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ON THE
DEVIATIONS OF THE COMPASS

[illegible] V

PRACTICAL ILLUSTRATIONS

OF THE NECESSITY FOR ASCERTAINING

THE DEVIATIONS OF THE COMPASS,

&c. &c.

11°
10°
9°
52°
Dingle
Blaskets
Dingle Bay
Valentia Hr.
Light F.
I
R
Kenmare
Skelligs
Two Lights F.
Kenmare River
Bantry
Dursey I.
Bantry Bay
Bear haven
Dunmanus Bay
Light F.
Mizen Hd.
Clonakilt
Glandore
Toe Head
Baltimor

PRACTICAL ILLUSTRATIONS

OF THE NECESSITY FOR ASCERTAINING THE

)EVIATIONS OF THE COMPASS

WITH EXPLANATORY DIAGRAMS,

AND

E ACCOUNT OF THE COMPASS SYSTEM NOW ADOPTED IN THE ROYAL NAVY;
NOTES ON MAGNETISM, &c.

BIBLIOTHECA · BODLEIANA ·

BY

CAPTAIN EDWARD J. JOHNSON, R.N. F.R.S.
SUPERINTENDENT OF THE COMPASS DEPARTMENT OF THE ROYAL NAVY.

LISHED UNDER THE SANCTION OF THE RIGHT HONOURABLE THE LORDS COMMISSIONERS OF THE ADMIRALTY.

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1852.

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PREFACE.

THE principal part of this book was printed for private circulation, with the view of assisting the Author to reason away any prejudices he might happen to meet with in the course of his official duties, while occupied in establishing a regular system of Compass Observations on board all her Majesty's ships; but on the recommendation of several Officers, well acquainted with the subject, the work in its present extended form has been submitted to the Lords Commissioners of the Admiralty, and is now published under their Lordships' sanction.

The object of the publication is expressed in the Title; viz. to illustrate the necessity which exists for ascertaining the Deviations of the Compass on board all ships — to induce improvements in that important Instrument — and to secure, by systematic arrangements, accuracy in the observations, and a proper application of their results to the purposes of Navigation.

In order to accomplish this object it has been deemed essential to remark upon the errors produced by different causes,— such, for example, as the aggregate influence of the ship's Iron upon the Compass, — the errors produced by small portions of Iron when allowed to remain near it,—those caused by the reciprocal action of Compasses upon each other,—the imperfection of the instruments themselves,—and the errors occasioned by taking bearings from parts of a ship where the deviation has not been ascertained; and in confirmation of such remarks it has been found necessary to quote, from among the numerous letters of Officers, and other documents, the details of a few cases bearing upon each branch of the subject: first, showing the serious evils which have arisen from errors of the Compass so produced; and secondly, pointing out the benefits which have already been derived from the practical application of the system recommended.

The Tables of Deviations of the Compass actually observed on board every class of her Majesty's ships, together with the diagrams illustrating the divergence which would thereby take place from the proper course if left uncorrected, are intended to induce caution, and to inculcate constant observation; while the "Practical Rules" and "Working Diagram" point out the way of ascertaining the necessary corrections, and the manner of applying them.

Some account of the Compass System adopted in the Royal Navy, the method of testing the instruments, placing them on board ship, &c., has also been inserted; and the observations upon the influence of the "Iron Diagonal Riders," now so often introduced into the structure of ships, have been added, not only as a warning respecting their effect upon the Compass in ships of war, but as being equally applicable to those of the merchant service.

In conclusion it only remains to be observed, that, in the brief Sketch of Magnetism contained in the last pages, it has not been considered necessary to separate the subject into different parts, the chief design of placing it in a work of this nature being to remove some misapprehensions which occasionally prevail in practice, and to call the attention of naval men to those publications where every branch of magnetism has been discussed in detail.

1847.

NOTE TO THE SECOND EDITION.

ALTHOUGH this Edition is printed in octavo, it contains all the Tables, Charts, and Letterpress of the former volume, with many additional facts which experience has elicited, and which are necessary to be known in the practice of Navigation. Among such facts may be mentioned the great difference in the Deviations of such Steam-ships as have what are termed Telescopic Funnels, under the two conditions of the said Funnels, viz. *up* and *down;* those produced by the introduction of iron in the repair of timber-built ships; the errors which arise from the compass bowl itself, when made of impure brass; and the changes which take place in the deviations of some iron ships, although their armament and iron work, with respect to the compass, remain in the same position.

1852.

CONTENTS.

PAGE

Chart of the English Channel, with Diagrams illustrating the errors to which Ships are liable in their course on account of the *Deviations of the Compass.*

A small Chart and "Working Diagram" explanatory of the method of correcting the courses and bearings for the Deviations.

General Remarks :

On the Deviations of the Compass caused by the aggregate influence of the Ship's Iron upon the Magnetic Needle, according to the Direction of the Ship's Head 1

Authorities of different Periods for the Notice of this Effect 3

Note on the Dispersement of Convoys 4

Wreck of the Apollo frigate and forty sail of Merchant-vessels on the 26th March, 1803 4

Note on the Loss of the Reliance 5

Letter of the Officer in command of H.M.S.V. Alban, relating the fact of that Vessel having been run into danger on account of the Errors of the Compass 12

Letter of a later date from the said Officer, after the Iron had been removed from the vicinity of the Compasses, the Vessel swung, and the Deviations ascertained 14

Report of Lieut. Keane, R.N. upon the Errors of the Compasses of H.M.S.P. Merlin 15

Communications from experienced Officers who have commanded Steam-vessels in Narrow Seas and difficult Navigations 19

Reports of Mr. Ellis of the Royal Yacht Victoria and Albert 20

Reports of Mr. Emmerson commanding H.M.S.P. Urgent 22

Conclusions drawn from these Reports 24

Remarks upon the Deviations of the Compass ascertained on board fifteen of H.M. Steam-vessels, eleven Iron Steam-vessels, and fif-

PAGE

teen of H.M. Ships-of-war of different Rates, with reference to the Tables I. II. and IV., and to the six Diagrams illustrating the Divergence in their respective Courses drawn upon the Channel Chart 26–28

Observations on the Danger of Vessels, wherein the Deviations have not been ascertained, entering a Port by the bearing of *one* object: Explained also in the "Working Diagram," No. VII. 30–31

No Dependence whatever to be placed on Bearings taken from different parts of an Iron Ship without the Deviation having been previously ascertained at the position of the Instrument. See Tables IV. and VIII. 34–35

Supplementary Table to No. IV. showing the Deviations of H.M. Iron Ship Birkenhead at different Periods 36

Table showing the necessity of re-swinging Iron Steamers, whenever any alteration has been made in the Boilers, Funnels, or Machinery 37

Report from the Commander of the Iron Steam-ship City of London, showing that the Correction of the Compass by Magnets is not permanent 38–40

Remarks on the Errors produced when portions of Iron Work or moveable pieces of Iron are allowed to remain near the Compass 41

H.M.S. Courageux, 74 guns, Capt. Wilkinson, proved to have been run upon a Reef near the Island of Anholt, Nov. 13, 1812, in consequence of the Arms under the Half-deck having attracted the Compasses 42

Evidence adduced at the Court Martial 43–44

Compasses of H.M.S. Hastings shown to have been attracted by the Iron Stanchions on the Main-deck 45

Letter of Captain B. C. Cator, R.N., relating a particular case of the Compass having been attracted by Iron Bolts which had been driven into the Deck near the Binnacle of H.M.S. Actæon 46

Letter of Sir John Franklin, relating a similar case to the above, which occurred in H.M.S. Bedford, 74 guns 47

Table of Deviations ascertained on board H.M.S.V. Styx under three different circumstances, showing the effect of Iron when differently placed with respect to the Compass 51

Remarkable Change in the Deviations of H.M. Steam-sloop Salamander after repair 52

Change of Deviation produced by an alteration in the Armament .. 54

Marked Change of Deviation which is produced by lowering what are termed the Telescope Funnels of Steam-ships 55

Table of Results obtained on board the Blenheim and Ajax 57

PAGE

On the Errors caused by the reciprocal action of Compasses upon each other, when (as is generally the case) the Binnacles are placed too closely together 58

Table of the Results of an Experiment in proof thereof 59

On the Imperfection of the Compasses 60

On the Errors produced by the impure Brass in Compass Bowls 63

On the rough Usage, &c., of Ships' Compasses, and of the erroneous Supposition that correct Bearings may be obtained from any part of a Ship, without having ascertained the Deviations of the Compass in the particular place from which such Bearings have been observed 64–65

Some Account of the Measures adopted for improving the Compasses of the Royal Navy, the Plan of testing them, and the System of placing them on board her Majesty's Ships, ascertaining the Deviations, &c. &c. 66–76

Reports from Officers on different Stations of the working of the Standard Compass 77

Result of the Trial of different kinds of Compasses in boisterous weather 78–80

Trial of Compasses on board Ship when the guns are fired 81

Admiralty Memorandum with reference to the removal of Iron-work from the Vicinity of the Compasses 84

PRACTICAL RULES for ascertaining those Deviations of the Compass which are caused by the Iron in the Ship 87–98

Constant Observations with the Standard Compass recommended .. 100

Table of the Deviations of the Compass of H.M.S. Erebus, in different parts of the World, as ascertained by Captain Sir James Clark Ross during his late Voyage 103

Tables of Deviations of Steam-vessels in different parts of the World 104–105

Notice of new Pamphlets on the Deviation 106–108

Table showing the Change of Deviation in H.M. Iron Steam-vessel Bloodhound 109

Influence of "Iron Diagonal Riders" upon the Compasses 112

Remarks upon the Effect which the heeling of a Ship produces upon the Deviations 117

Table of Results obtained on board H.M. Iron Steam-vessel Bloodhound under the following circumstances: 1st, when upon an even Keel, both when the Fires were extinguished, and when they were lighted and the "steam up;" 2dly, when the Vessel was heeled Eight Degrees to Port; and, 3dly, when heeled Eight Degrees to Starboard 118

PAGE

GENERAL OBSERVATIONS ON MAGNETISM :

Works in which it has been discussed in detail 121

Methods of Magnetising Steel by the "single" and "double touch," and also by the galvanic process 124

Compass affected by Lightning 126

Magnetic Power of different kinds of Iron 129

Remarks on Electro-magnetism 131

Brief Notice of different Theories 134

Notice of the Measurement of Terrestrial Magnetism by the System of simultaneous Observations over the greater part of the Earth's surface 137

Remarks upon the *Isodynamic*, *Isoclinal*, and *Isogonic* Lines represented in the Magnetic Maps 138

Table showing the Change of Variation and Dip at different Places during different Periods 141

Table showing the Diurnal Variation of the Magnetic Needle at Greenwich during the year 1842 145

Concluding Remarks, with a Table exhibiting in approximate Chronological Order some of the Discoveries respecting the Compass 147

Additional Notes on the Local Attraction of Ships 149

Case of the Diligence Transport 159

Results of Experiments with Iron Cylinders 163

Case of H.M.S. Rattlesnake 160

Notes on Compasses designed by different Individuals 164–166

Explanation of the "Working Diagram" 167–169

Notice of Mr. J. R. Napier's Graphic Plan of delineating the Deviations 170–172

ON THE

DEVIATIONS OF THE COMPASS.

GENERAL REMARKS.

WHILE the tides and currents of the ocean—imperfect logs—inaccurate charts—unsteady steerage—inattention to the lead—stress of weather—defective ships—defective equipment or defective management—may be the cause of loss, it would be fallacious to assume that the greater number of wrecks* are caused by errors of the compass; but that many have occurred in consequence of these there can be no doubt whatever, as will be shown in the succeeding pages, and without at all undervaluing that old and sensible motto, "Lead, log, and look-out!" which, under all circumstances, should be preserved and acted upon: yet every rational seaman will admit that, wherever a *cause* of error is proved to exist, the amount of such error should be ascertained, and due allowance be made for the same in navigating his ship.

The statement "that ships have been, and are still, navigated across the seas by persons who have no knowledge of the '*deviations* of the compass,'" is certainly not an argument against the correction of proved errors; and although prejudice or inattention may frequently prevent their detection, yet the evidence hereafter adduced will clearly show that such errors have not only placed ships in danger, but have actually, on many occasions, caused their total wreck.

---

* The annual average number of wrecks of British ships is stated to be about 547, or, as has been quaintly observed, "a ship and a half a-day."

It may be necessary in this place to premise that, throughout these pages, the term *deviation* is to be understood as signifying the error of the compass produced by the iron in the ship, and altogether independent of the *variation*, although allowed for in a similar way, as will be hereafter explained.

The following are some of the prominent sources of error in a ship's course, as relates to the compass, independently of those which may arise from tides, currents, or unsteady steerage.

I. The DEVIATIONS of the compass caused by the aggregate influence of the ship's iron upon the magnetic needle, according to the direction of the ship's head.

II. The errors produced when portions of iron work, or moveable pieces of iron, are improperly placed near the compass.

III. The errors caused by the reciprocal action of compasses upon each other, when (as is generally the case) the binnacles are placed too closely together.

IV. The imperfection of the compasses themselves, the weakness of the magnetism of their needles, the occasional oblique direction of the magnetic axis in such as have flat bars, the distortion of the compass cards, the imperfection of their pivots and caps, inefficient suspension, and balancing, and the want of concentricity in the general construction of the instrument.

V. Rough usage and inattention to the occasional examination of the pivots, caps, needles, and gimbals, the improper mode of keeping the cards, and also the erroneous supposition that correct bearings may be obtained from any part of a ship without having ascertained the *deviations* of the compass in the particular place from whence such bearings have been observed.

I. *On the deviations of the compass caused by the aggregate influence of the ship's iron upon the magnetic needle, according to the direction of the ship's head.*

In directing a ship's course, every seaman is aware of the necessity for making due allowance for leeway, the set of the tides or currents, and also for the "variation of the compass;" but it is by no means so usual to find that proper attention is paid to the efficiency of that important instrument, or that the necessary precautions are taken to ascertain and allow for the other errors, independent of *the variation,* to which it is unavoidably subject.

As a proof of the truth of the above remark, it may here be noticed that, notwithstanding the errors to which ships are liable in their course, on account of their local attraction exerted upon the compass, having been known since the year 1684,* and from that period up to the present time occasionally noticed and commented upon by intelligent mariners and skilful officers;† notwithstanding that the subject has been so clearly elucidated from time to time by so many learned and able men, and its dangerous effects to the practical navigator, if unattended to, demonstrated in the most palpable way by officers employed in the Arctic expeditions (see Notes at the conclusion); notwithstanding the numerous instances recorded in periodical and other publications by intelligent officers, and also by lecturers in public institutions, where the most serious accidents have occurred in consequence of inattention to the *deviations* of the compass,—it is not more remarkable than true that, with a few exceptions, such as in ships employed on voyages of discovery and surveying expeditions, until of late years very little heed was ever taken about the matter, until some disaster had occurred, which rendered investigation indispensable; and then the error and its cause became too palpable to be longer overlooked.

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* Capt. Samuel Sturmy's "Mariner's Magazine."

† Dampier, 1691-1693; Mr. Wales, astronomer to Capt. Cook, 1776-1780; Mr. Downie, 1790; M. Beautemps Beaupré, 1793; Capt. Flinders, 1801-5-10; Mr. Bain, 1817; Parry, Ross, Sabine, 1818-1820 (see also a note at the conclusion extracted from Sabine's "Pendulum and other Experiments," 1825); Buchan, Fisher, and Beechy, 1818; Mr. Scoresby, 1819; Professor Barlow, 1819, and his valuable "Essay on Magnetic Attractions," 1824; Captains Basil Hall, Baldey, Owen, Vidal, Mudge, Clavering, and Forster, 1820-1823; various papers by Professor Christie in the "Philosophical Transactions," 1821-1833; Capt. Martin White's "Channel Sailing Directions;" numerous articles in the "Nautical Magazine," by Capt. Becher, from the time of its commencement to the present period, particularly that of 1837; Raper's "Practice of Navigation," 1840; several papers by Mr. W. Walker, published in the "Nautical Magazine," containing "Remarks upon the Loss of the Apollo frigate and forty of her convoy," and some very remarkable facts which came under his (Mr. W.'s) view during his service afloat: and lastly, in point of date, though not of least importance, the observations of Sir James Clark Ross and Capt. Crozier during the Antarctic expedition.

Officers in charge of convoys during the war will probably remember the care with which the general signal was displayed at sunset, "to steer a given course during the night;" with what alacrity that signal was repeated by the ships-of-war in their stations, and answered by every merchant-vessel in the fleet; and they may also possibly remember with what surprise,—nay, indignation,—they observed, when daylight came, almost the entire convoy dispersed over the ocean as far as the eye could reach, and mayhap a suspicious-looking stranger or two escorting those farthest away, farther astray, in despite of all the shots fired during a morning watch to recall them.

That such dispersements were in part attributable to the difference of the compasses in each ship, according to the position of the iron affecting them, there can be no doubt; but the greatest delinquents in this particular, in all probability, were not the merchant-vessels, but rather the ships-of-war; the attractive power of their guns upon the binnacle compasses being now a well-known and constantly proved fact.

The wreck of the Apollo frigate and forty of her convoy on the coast of Portugal, on the 26th March, 1803, alluded to by Mr. Walker,* and by Captain Cator in his letter, is by many persons supposed to have been occasioned by the errors of the compass; and a similar supposition obtains respecting the awful wrecks of some of our line-of-battle ships on the coast of Jutland and Holland, in 1811: but, to come nearer to the present day, an able writer in "The Times" maintains (and with great show of reason) that that lamentable event, the loss of the Reliance Indiaman, on the coast of France, was attributable to similar errors.

In order, however, that the reader may judge for himself in this case, the relation of the catastrophe and the letter alluded to are here quoted:—

"LOSS OF THE RELIANCE.

"The survivors among the crew of the ill-fated Reliance arrived in London yesterday afternoon by the General Steam Navigation Company's vessel Magnet, Captain Stock, from Boulogne.

"The Magnet brings over the whole of the surviving members of the crew, with the exception of Dixon, the carpenter, who is still detained by the consul, Mr. Hamilton, for the purpose of identifying the dead, only twelve bodies out of the hundred and nine persons lost having been picked up when Captain Stock left.

"The subjoined statement, made by O'Neill, an intelligent foremast man, and one of the two Englishmen saved, who was on deck when the vessel struck, coupled with an important and affecting letter, written at sea by Captain Green to his brother, on the 4th instant, and received since the wreck, and an extract of another letter written by one of the mates twenty-eight hours before the calamity occurred, and picked up on the French coast, leaves no doubt as to the circumstances under which the Reliance was lost.

"O'Neill states that they had had remarkably thick and hazy weather for some days previous to the 12th instant; and on Friday they shortened sail, and the lead was kept going. At half-past twelve o'clock at night, one of the crew, named Thomas, whose watch it was on the forecastle, reported that he saw lights, and soon after they were distinctly observed by several others on the larboard and starboard-bows. The second mate, Mr. Green, was on duty at the time, and said that those on the weather-bow were a ship's lights, and added, 'Hurrah, boys, the light on the lee-beam is Dungeness. We shall be in the Downs this morning.' They then steered on and thought they were running for the Downs. Their course was east by north, as it was given at twelve o'clock, when the look-out was relieved. About one o'clock Captain Green, and Mr. Walsh, the chief mate, came on deck, and the captain immediately gave orders to wear the ship, and heave the lead. As the vessel answered her helm the quartermaster gave the soundings, 'By the deep, six.' At this moment, the vessel, under close-reefed fore and maintop-sails, was paying off before the wind, and gradually going round on the other tack. A seaman, named Munroe, was at the wheel at this time; and as she veered round her heel touched the bottom, and she struck heavily on the sand. The shock is described by O'Neill as terrific. His language was, 'It struck me as if I had laid hold of an electrical machine.' The whole of the crew rushed on deck, and, before any orders could be given she shifted slightly, and became more firmly imbedded. This motion was repeated five or six times in rapid succession; and it was the opinion of the officers that the ship's back was broken by the force of the concussion. The captain immediately ordered signals of distress to be fired. It was the opinion of all on board that they were off the English coast; and the captain, seeing that there was no hope of saving the ship, desired several of the crew to cut away the mainmast. This was immediately commenced, and in a few moments it went over to leeward with a terrific crash. The foremast soon followed, and, in falling, broke the leg of a young midshipman, named Forde; but the imminent danger of all around did not prevent, even at this crisis, every attention being shown him. The fractured limb was carefully set by the surgeon, and the poor lad was conveyed to the captain's cabin, where he remained until the breaking up of the ship obliged some of the crew to place him on the poop. While Forde was lying in the cabin, O'Neill and two other seamen made their way there, and took away a musket, a couple of pistols, and a bag of powder, with which they fired signals from the poop. Subsequently, at the captain's direction, who, according to O'Neill, manifested the greatest coolness and presence of mind, lights were placed in the mizen rigging, in order to point out their position to any boats that might come off to their assistance. The sea was now tremendous, and, as the vessel rolled, her bottom could be distinctly heard breaking up. The water rushed in, and her cargo of tea becoming wet, burst up the decks, which, for some time previous, had been dangerous to stand upon, from the planks opening and shutting, whereby the feet of several seamen were jammed between the seams. Three hours had now elapsed since the vessel struck, and the day was beginning to break. The captain, with the officers and passengers, and many of the crew, were on the after-part of the vessel, which still held together, the sea making a breach right over her. Chests of tea floated one by one on the surface, indicating that a portion of the bottom was entirely gone. Orders were now given to get out the long-boat; but, from the injuries she had sustained from the falling of the masts and rolling of the ship, she was found to be useless. There were two other boats on board, but their condition at this time, as O'Neill states, was such as to render them of no service. The Europeans among the crew were then desired by the officers to construct a raft; but this could not be accomplished. In fact, O'Neill admits that the crew refused to work at it. His statement is:—While some of them were working at it, one said to the other, 'Why don't you lend a hand? I sha'n't work if you don't!' and they all left off together. Several of the crew sought refuge on the masts and rigging that had gone to leeward, where, amidst the loose chests of tea and spars, a most precarious position continued for some time to be maintained. The vessel held together until eight o'clock A.M., rolling fearfully from side to side with the swell of the ocean, and drenching the crew continually. About this time, Captain Green, the first mate, Mr. Walsh, and several others, left the poop of the ship to take refuge with the sailors in the spars and rigging of the mainmast, Captain Tucker and many others still remaining on the after-part of the vessel. Shortly before nine o'clock, as nearly as can be ascertained, the vessel parted amidship, the sea breaking right through her, and in a few moments she was a complete wreck, portions of her timber floating about in all directions. Numbers of the crew sank immediately, and were entirely lost sight of amidst the breakers; Captain Tucker was among this number. The captain, Mr. Walsh, O'Neill, the sailmaker, the armourer, and several others, still clung to the mainmast and rigging, which being released from the vessel, floated towards the land. At this period, and indeed for some length of time previous, the people on the coast were distinctly observed running to and fro, but no boats put off to render assistance. The floating timber from the wreck, whirled round by the violence of the sea, struck off many of the poor wretches who had taken refuge on those portions still above water; and the incessant fatigue which the crew had been subjected to for some hours rendered their efforts of swimming towards the shore, a distance of nearly three miles, extremely feeble. Captain Green, who was nearly sixty years of age, became so weak that he lost his hold several times and fell into the sea. Mr. Walsh called out to some of the sailors, 'Pull up the captain, boys!' and he was raised on to the timber more than once. The last time he was taken out of the water he was found to be insensible, but the men still assisted in holding him on. About half-past nine o'clock, the loose spars became so exposed to the sea as no longer to afford protection against its violence, and the greater number of those who had sought refuge upon them were washed off. O'Neill plunged into the sea and seized a plank. At the moment of doing so, several sailors clung to him. He was compelled to strike them off to save his own life, but one of the Malays reached the shore with himself. O'Neill states that, as daylight broke, men on horseback were observed on the shore. Both the Malay and O'Neill were insensible on reaching the shore."

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* See Notes at the conclusion of these Remarks.

" THE LOSS OF THE RELIANCE.

" *To the Editor of The Times.*

" Sir,—Of the causes that may be conjectured to have occasioned the loss of the Reliance, perhaps the most probable is, that the proper allowance was not made for the deviation of the compasses, caused by the local attraction of the ship. In all ships in northern latitudes the north point of the compass is attracted towards the ship's head—the deviation thus caused is greatest when the ship's head is on the magnetic east or west. In sailing-vessels it frequently amounts to half a point or more. The proper magnetic course for a vessel coming up Channel is a little to the south of east, consequently the deviation of the compasses is then near its *maximum;* and if not known and allowed for, the effect would be to make the vessel's course lie to the south of her proper course by the whole amount of the deviation. According to your correspondent, 'A Shipmaster,' an error of a point and a quarter in a vessel's course from Beachy Head would run her on the French coast. In another paragraph of your paper to-day it is stated, on the authority of the carpenter, that the weather had been so hazy that no observation had been taken for seventy hours. I may therefore assume that an error of half a point or less in the vessel's course, in a run of seventy hours, would be sufficient to take her to where she was wrecked. Pilots are, I believe, in the habit of making some allowance for local attraction without being aware that they are doing so. At least, I have been informed that the compass courses they use for vessels going up and down Channel are not opposite to each other; and they find by experience that, if they use opposite courses, the vessel is thrown too much to the southward.

"The practice of determining and allowing for the local attraction of ships has only recently been introduced into the navy. Even in the navy it is only partially used, and probably not at all in the merchant-service.* If the captain of the Reliance took his course from a chart, or from sailing directions in which no allowance was made for local attraction, or if the deviation of the compasses in the Reliance was a little greater than usual, it is almost certain that the proper allowance was not made, and that the vessel's course was in consequence too southerly. This explanation seems to me much more probable than that of 'A Shipmaster.' The distance of the lighthouses on Dungeness and Cape Grisnez is stated by him to be twenty-three miles. Even in clear weather it is not probable that either light can be seen at more than twenty-three miles' distance, when the difference of bearing would be much greater than any accidental yaw of the ship. That the Reliance took a wrong course is certain. It is not likely that this was caused by any current or leeway not allowed for, and still less that it arose from any fault of the men at the helm, in not keeping the vessel on the course given them. The conclusion seems almost irresistible, that the error arose from the deviation of the compasses not being allowed for. Compasses, made as they usually are, with a flat horizontal needle, are subject to another error, which may have affected those of the Reliance; the axis of magnetism is liable to change. But if this error existed, as it is the same in all courses, it might have been discovered and allowed for, whereas deviation is different in different positions of the vessel's head, and in different latitudes. It is almost certain that the deviation of the compasses of the Reliance did exist in the direction and to the amount that would cause the error in her course, and more than probable that the officers did not know and make allowance for the deviation.

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* 1850. It is now universally adopted in the Royal Navy, by order of the Lords Commissioners of the Admiralty.

" *Lincoln's Inn, Nov.* 19." " A. B.*

(*Times*, Nov. 23, 1842.)

Mr. Smith's view of the cause of loss of the Reliance is strongly corroborated by a circumstance mentioned by Mr. Walker, in a communication to the " Nautical Magazine," a quotation from which is here inserted.

" The following extract," observes Mr. Walker, " is from a newspaper dated April 1, 1843:—' During the last ten days, Mr. Kent and his associates, who purchased the wreck of the Reliance near Boulogne, have been busily employed in their endeavours to bring the wreck to land; they have found a chronometer, several silver and plated dishes, and *a large iron* tank, forty-six feet long by eight feet deep and six feet wide.'

" Having made inquiries," continues Mr. W., " I was informed by a gentleman who knew the ship, and had seen the tank, that it was placed abaft the mainmast, and before the binnacle, and probably eighteen feet below the compass. Now here was a tank of malleable iron that would exert a magnetic action upon the compass as powerful as that of a solid mass of iron of the same linear dimensions, that is equal to 2208 cubic feet of iron, which would weigh 468 tons."

From the position of this tank, as before described, it is evident that in these latitudes it would exert an influence to draw the north end of the needle away from the correct magnetic north, according to the direction of the ship's head; and when that was to the eastward, it would be drawn to a certain extent towards that direction, or, in other words, that *easterly deviation* would be produced; and hence the ship's course would be in reality more to the southward than that indicated by her compass.

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* The author of the above letter, having subsequently written an article upon the loss of the Solway steam-ship, is known to be Archibald Smith, Esq. M.A. late Fellow of Trinity College, Cambridge.

But it is not necessary to pursue further the very strong probabilities as to the cause of this ship's loss, more particularly as the errors of the compass, which have been proved by actual experiment upon upwards of a hundred of her majesty's ships and steam-vessels (under my immediate superintendence) to exist, would, if not properly attended to and allowed for, unquestionably lead to the most disastrous consequences. (See a portion of these numerical results and their illustration, diagram No. 1.)

Since the gradual introduction of so much iron into the art of ship-building, from the knees to the very davits, and more especially from the huge masses of that metal employed in the construction of steam-ships and their machinery, the large amount of *deviations* of the compass cannot be a matter of surprise; but that these should not upon all occasions be properly ascertained, and be made an element in the ship's reckoning, is an anomaly not so easily accounted for.

Before proceeding, however, to comment upon the Table of Results, already referred to, the account of a recent occurrence to one of her majesty's steam-vessels, related by her commander, a careful and experienced officer, may serve to impress the minds of those in charge of such vessels with the absolute necessity which exists for ascertaining and allowing for the *deviations* of the compass.*

(Copy.)

" *H. M. Steam-vessel Alban, Woolwich, Dec.* 6, 1842.

" Sir,

" There being a great degree of local attraction on board this vessel, under my command, which has frequently thrown me out of my reckoning to a serious amount, whilst employed coasting, which is the general way in which I am employed, I beg leave to request that you will be pleased to examine my compasses, and also to cause one of the standard compasses to be fitted on board.

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* Be it observed, that this vessel had no guns on board; therefore, whatever deviation existed was due to the iron of the ship.

"I further beg leave to state that, on one occasion, when leaving the Longships, I steered north for sixteen miles, and then N. by E. for the Tuscar Lighthouse, on the coast of Ireland, which being one point and a half to the northward of the Smalls Rocks, I fully expected to have cleared them to the northward—(at this time the weather was extremely thick)—when, to my surprise, I found myself in a most dangerous situation, close to the South Bishops, on the Welsh coast; and had it not been for the lighthouse recently erected there, the vessel must inevitably have been lost.

(Signed) "JOHN KING, R.N.
Commanding H.M.S.V. Alban.

"*To Captain E. J. Johnson, R.N. Admiralty.*"

From the Alban's position, sixteen miles north of the Longships Light (marked P, diagram No. 6, on the chart), the correct magnetic bearing of the Tuscar is N.N.E. and that of the South Bishops N.E.½N. nearly, making a difference of no less than 17°; and yet the commander of the Alban, having shaped a course N. by E. by his compass (see the dotted line on the chart), which is a point to the northward of the bearing of the Tuscar, and no less than two points and a half to the northward of the bearing of the South Bishops, finds the vessel, after a run of less than 100 miles, close to the dangerous rocks on the coast of Wales, and narrowly escapes being wrecked, instead of being, as he expected, in the fairway for Ireland.

Making every reasonable allowance for the set of the tides, there does not appear to be any rational mode of accounting for the position of the Alban, except by the *deviation* of the compass.

On conversing with the commander, I found that this was only one out of many instances from which he had reason to infer there was a great amount of local attraction exerted upon his compasses; and on going on board the vessel, all surprise ceased on the subject, for the improper proximity of iron to the compass was such, that it was impossible but that a large amount of deviation must have been occasioned: therefore this case may also be considered to bear upon the second division of the subject.

On application to Sir F. Collier, who, from the first, has been a firm supporter of these compass reforms, this iron was removed, a standard pillar was fitted for the compass, and the Alban having been swung at Greenhithe, and the deviations of the compass duly ascertained, according to the "Practical Rules" published by order of the Lords Commissioners of the Admiralty, she again proceeded to sea.

The following is a copy of a letter from the commander of the said vessel, dated some time afterwards, which will show the result of the precautions taken and the system adopted :—

"*H. M. Steam-vessel Alban, Sheerness, Jan.* 24, 1843.

"Sir,

"With respect to the standard compass G 35: in going to the westward, allowing the deviation, we made the Headlands, Owers' Light, and St. Helen's very exactly, twice using the cards C and D; but I have used C most: but in coming to the eastward, I have found that we have gone a little to the southward, which might probably be owing to bad steering. The card A, I have used very little, as we have been in no heavy sea since the standard has been erected. I beg leave to say that I place great confidence in the compass.

"I have, &c.

(Signed) "JOHN KING,

"Commanding H.M.S.V. Alban."

Every well-informed seaman must have remarked the very striking differences between the courses indicated by compasses in different positions on board the same ship, and pilots find by experience that it is necessary to steer different courses in different ships to pass through the same channels; it is, therefore, not surprising that, with all the care they take to steer a proper course, making also due allowance for the set of the tide, that, on their first trial of a ship, such serious mistakes are made in thick weather or at night, even in steering from headland to headland, or from buoy to buoy, the latter being often missed from no other cause than the *deviation* of the compass. A case in point will be found in the letter of an experienced pilot inserted at the bottom of this page.*

On referring to the Table of Deviations of the Vesuvius, ascertained under my superintendence at Greenhithe, I find that on the N.E. course there is 10° (or nearly a point) *easterly deviation;* so that Mr. Stuart very properly made that allowance.

The letter of Lieut. Keane, commanding H. M. packet Merlin, bearing so clearly upon the same subject, is likewise here inserted.†

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* "*Woolwich, May 14th,* 1845.

"Sir,

"After leaving Greenhithe with her majesty's steam-ship Vesuvius, and proceeding down Swin, had I not have known the error of the compass you told me of, I must have run the ship on shore, as it was night-time. In steering down from the Sunk my course is N.E. and I had to steer N.E. by N., and with a flood-tide just kept clear of the Shipwash. In fact, sir, I found that to be the case in steering a north-easterly course.

"I remain, Sir, your very humble servant,

"RICHD. STUART, Pilot.

"*To Captain E. J. Johnson, R.N.*"

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† "*H. M. Steam-packet Merlin, Nov.* 7, 1842.

"Sir,

"I beg leave to draw your attention to the compasses of H. M. steamer under my command; having three compasses standing on the quarter-deck, at different distances from each other and from the wheel, and finding they materially differ from each other, I beg to offer the following observations for your consideration.

"There being a number of fixed beacons on the shores at the entrance of the Mersey, which form the guides through the channels, and whose bearings have been determined by Capt. Denham and Mr. Lord, I have found that, in proceeding in and out through those channels, that two out of the three compasses vary from a half to three-quarters of a point from the true north, the compass standing on the starboard side of the quarter-deck being generally correct, according to the bearings of the landmarks; the larboard compass varying nearly three-quarters of a point to the eastward, and the compass in

Having represented the case of the Merlin, the Lords Commissioners of the Admiralty authorised me to place a standard compass on board; and the necessary precautions having been taken respecting the iron work, that vessel was swung and the *deviations* ascertained.

The result has proved highly satisfactory; and Lieut. Keane, in his last official Report (Liverpool, Nov. 1845), states, "that, with respect to the cards A and C, nothing can be more correct than they continue to be with respect to the local bearings of the landmarks in these channels."

In some vessels the amount of *deviation* is small, and in others it is so large as to be quite sufficient to cause the loss of a ship, even during a short run; while in others again, from the position of some iron stanchion, bolt, bar, or stand

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the middle of the deck, twelve feet from the wheel, varying from a half to three-quarters of a point to the westward of the starboard compass.

"Whenever the ship's head comes to the north or south points of the compass, the compass on the larboard side of the quarter-deck also becomes correct, inasmuch as it agrees with the starboard compass, the midship compass still varying its three-quarters of a point.

"When the ship's head is steering either east or west by the starboard compass, the midship compass agrees with the starboard compass, and the larboard compass varies nearly three-quarters of a point.

"On joining the Merlin, I considered the deviation in the compasses might be caused by the close proximity of the rudder-head, where there is a considerable quantity of iron; and I moved the binnacles nearly eighteen inches farther away.

"I various times changed the compasses to ascertain whether the fault lay in the card, but found no card that would give the true bearings, either on the larboard side or midship compasses on the deck.

"From many years' experience the pilot has always found those two compasses at variance from the true point, and the habit has always been, in consequence of such deviation, to steer by the starboard compass.

"I wish much you would inspect the compasses, and ascertain if you think it necessary to fit a pillar compass, as we have constantly to run backwards and forwards in thick weather, when we can seldom see half a mile from the ship, and everything depends on the correctness of the compass-course, and we have proved beyond a doubt that the larboard and midship compasses are not to be depended upon in thick weather.

"I have the honour to be, Sir, your obedient servant,

"E. KEANE, Lieutenant commanding.

"*To Capt. E. J. Johnson, R.N. Admiralty.*"

of arms, the error may be changed in a contrary direction; so that the *deviation* in one vessel is not a guide to its *amount* or *direction* in another, and there is no other remedy but ascertaining the fact by direct experiment in each ship, as described in the "Practical Rules," a copy of which will be found at the conclusion.

It is proper that I should mention in this place, that these "Practical Rules," and likewise the plan upon which the Standard Compass is constructed, are the joint productions of the Compass Committee appointed by the Lords Commissioners of the Admiralty. The Members composing the Committee were:—Captain (now Rear-Admiral Sir) F. Beaufort, K.C.B. F.R.S., Hydrographer to the Admiralty; Captain Sir James Clark Ross, R.N. F.R.S.; Lieut.-Colonel Sabine, R.A. F.R.S., Foreign Secretary to the Royal Society; S. Hunter Christie, Esq. F.R.S., Secretary to the Royal Society, and Professor of Mathematics at the R. M. Academy, Woolwich; Major Jervis, F.R.S.; and Capt. E. J. Johnson, R.N. F.R.S.

Several years ago, when crossing the North Sea in the steam-ship Superb, I noticed that the course steered from the river Humber to the entrance of the Sleeve was E.N.E., and returning in the same vessel, I observed that the course steered from the Sleeve to the Humber was W. by S., although the weather was nearly calm on both passages.

On inquiry I was informed, that when the exact reverse course (W.S.W.) had been steered the vessel had, "on making the land," been found to be out of her reckoning, and far wide of her port; and that the courses E.N.E. and W. by S. had been discovered by practice to be suitable, as leading into the Sleeve on one side of the North Sea, and towards the entrance of the Humber on the other, and had, consequently, been adopted as standard courses, except under extraordinary circumstances; and I had proof of their answering the desired purpose when "making the land" on both sides of this ocean, viz. the Holmen Beacon on the coast of Jutland, and the Spurn Lighthouse at the entrance of the Humber.

The examination of the chart did not enable me to attribute the *cause*, which rendered such a difference in the courses necessary, to currents; but on referring to a Table of Experiments I had made some years previously, as to the effect produced on the magnetic needle by an iron disc in various positions (after the system of Professor Barlow), there remained no doubt on my mind but that the ship's iron was the cause sought.

This case of the Superb* has been particularly described, because it is precisely similar to those which are constantly occurring, wherein a different course is found requisite to be steered to that mentioned either in the sailing directions or charts, and thus rendering those valuable documents comparatively useless, or, where the cause for such difference of course remains unknown, throwing an unjust suspicion upon their accuracy.

The officer commanding the Superb, having ascertained that the directly opposite courses by his compass did not lead him to his destined ports, wisely altered them to those which answered his purpose. But this practical experience of error on two points of the compass would not guide him accurately to that which existed upon the others; so that, whenever the vessel changed her station, where different courses might be required, it would only be again ascertained by practice that such and such courses (although they were those mentioned on the charts and in the sailing directions) did not lead to the intended ports.

But this discovery of error might be made too late; for, in the second instance, the day might have been hazy, or the night thick and dark, and the course steered according to the chart and sailing directions (but with the steamer's compass affected by the vessel's iron) might have caused her total loss.

If a ship were required to be steered between two dangerous rocks or into a harbour by the compass-bearing of one object only, it is evident enough that if there was much deviation of the vessel's compass when her head was on that point of bearing, she would inevitably be wrecked. (See diagram, No. 7.)

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* The Superb was afterwards lost upon the coast of Holland.

The Ethalion ran upon a shoal in the Gulf of Finland when steering, as the captain and master supposed, in the fairway between two shoals, according to the bearing of a point of land given in the sailing directions, as leading clear of them. The point of land did actually bear as directed; but then it was the bearing taken with the Ethalion's compass, which was found afterwards to have been attracted by some bars of iron under the quarter-deck.

Again, if in order to enter a harbour it were required, according to the chart, to bring two lights or leading marks in one line in a given correct magnetic bearing (say W.S.W.), then it is quite clear it would be *impossible* to bring such lights in one on that bearing by the Superb's compass while the vessel's head was in that direction,* nor by the compasses of the fifty steam-vessels which have been swung under my superintendence, as will be hereafter noticed.

Having from time to time communicated with intelligent officers who have commanded steam-vessels in narrow seas, and in the most difficult navigations, I cannot do better than quote in this place, from the mass of evidence I have on the subject, some of their own descriptions of the serious errors of the compass in their respective vessels:—

"*H.M. Yacht, Victoria and Albert, Deptford,* 16*th August,* 1843.

"Sir,

"I had the honour to receive your letter of the 16th ultimo respecting the error of compasses on board steam-vessels, requesting to be informed of any observations relative to this important subject that I may have been enabled to make during my employment in command of steam-ships. I therefore beg to acquaint you, that I have had ten years' experience in command of several steam-ships belonging to the St. George Steam-packet Company, on various stations in both Channels, on the coast of Spain, and in command of the Sirius between London and St. Petersburg, &c. &c. My other vessels ran or sailed between the ports of Liverpool, Dublin, Bristol, Cork, Glasgow, and London; and in all cases I have ever found it necessary in each vessel, notwithstanding I was supplied with the best and most approved compasses, to pay marked attention to the working and correctness of my compasses, to enable me to detect their error and establish a course for each vessel, as not one of them could be steered the same course precisely from buoy to buoy, or from headland to headland. Although I frequently removed my compasses and my officers and crew with me in taking charge of a strange vessel, so that in leaving port I always had the same helmsman, yet I have observed with great anxiety we never could pick up the buoys at night until I had been a sufficient time in the ship to establish a course from buoy to buoy, &c. or make an allowance for the error of the compasses, which in some ships was much more than in others; and from my constant communication with other commanders of steamers, I find they were frequently exceedingly out of their direct course from the same cause, which I must attribute to the great quantity of iron necessarily about steamers, but frequently too near the compasses, such as iron fastenings, iron tillers, chains, &c. On leaving the port of Liverpool, which is always at the same time of tide, when abreast of the Rock Light, I have sometimes steered W.N.W., other times W. by N., and N. W. by W. ½ W., and so on through the different channels, and the same difference between headlands; while in the Sirius, in going down Channel, instead of steering W.S.W. ½ W. from the South Foreland to Dungeness, I was obliged to steer W. ¼ S., from thence to Beachy Head W. by N. ¼ N. instead of W. ¼ N., and so on down Channel; but when steering near the north or south points of the compass the error was considerably less: but it was difficult to know which way to make the allowance for this error, which was generally about half a point, or rather less, when steering north or south. In consequence of the error and the difficulty and danger the ship was exposed to, the binnacles and compasses were moved repeatedly to different parts of the deck, and everything tried to remedy this serious difficulty, which was at last in a great measure reduced to a slight steady error by raising the compasses considerably from the deck, just so that the man steering could see the compasses well. This important difficulty I have constantly observed in steam-ships, which I hope and trust, and I feel convinced, will in a very great degree be obviated by the plan you have adopted in finding the error upon each point of the compass, so that an error will be established which can with ease and certainty be allowed for, and, consequently, a course be steered with safety.

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* See explanation of diagram, No. 7.

"I have the honour to be, Sir,
"Your obedient humble servant,
"Wm. Ellis, Master, Royal Yacht, Victoria and Albert.

"*Captain E. J. Johnson, R.N.*"

Mr. Ellis having had such constant and extensive experience in the command of steam-vessels, and now holding the honourable appointment of Master in the Queen's Yacht, it may be proper to insert in this place a copy of his letter after he had tried the standard compass on board her majesty's yacht, and the method of ascertaining and allowing for the deviation as explained in the "Practical Rules:"—

"*H.M. Yacht, Victoria and Albert, Portsmouth,* 18*th July*, 1845.

"Sir,

"I beg to acknowledge the receipt of your letter of the 11th instant, accompanied by a Table of the Deviations of the standard compass on board H.M. iron steam-yacht Fairy, and of this yacht when last swung in May 1845. With respect to the standard compass of the Victoria and Albert furnished us in July 1843, I have great pleasure and confidence to acquaint you that, from the several trials, both in fine and rough weather, and steering on every point of the compass during the last two years, we have had the most satisfactory proofs of its correctness, having run from headland to headland, several times across the Channel, up and down Channel, and in the North Sea, without having once occasion to alter the vessel's course, by a steady attention to the steerage of the ship, and making the necessary allowance so clearly pointed out in your statement to me on first starting this yacht. Permit me to add, that Captain Lord A. Fitzclarence will fully corroborate the above should it be deemed necessary.

"I have the honour to be, Sir,
"Your very obedient humble servant,
"Wm. Ellis, Master, Royal Yacht.

"*To Captain E. J. Johnson, R.N. Admiralty.*"

The following remarks are from Mr. Emerson, commanding H. M. steam-packet Urgent:—

"10*th July*, 1843.

"Sir,

"I trust you will pardon me for trespassing on your time by making a few remarks on the errors which I have generally found in the compasses. During many years' experience in narrow navigations I have found the compass most erroneous; hardly ever do the courses shaped make the land, lights, or buoys as expected, although every allowance has been made for set of tide, sea, and wind; and I can assure you that, without the most vigilant attention to the steerage, the distance run, and timely sounding, added to long practice, could we in fogs, &c. make our ports as we do. It is of no little moment to the public to do this, for if a mail be lost, that is, does not arrive in time, it is of no small consequence in a mercantile point of view; and yet, in spite of all anxiety and fatigue, in dense fogs, rain, or snow, we are obliged to run with the mails, and after all cannot make the object owing to errors in the compass. Sometimes I run two or three hundred yards to obtain a sight of headlands, lights, or buoys, or to hear the sound of a bell, and have then gone into port by the sound of bells or report of guns on the Irish side.

"At other times, in spite of every allowance that long practice and experience and watchfulness can suggest, I have failed, and could not make the object looked for, and then a delay is caused, and the mail lost for the night; and all because we had not one superior compass on board.

"Many times when there has been daylight enough I have purposely placed myself to the southward to make the breakers on the Kish, and then run along the edge of the bank in five to six fathoms, to be certain of making the Kish lightship.

"I will now give a few facts out of many that could be advanced to prove that almost all our compasses are erroneous, and vessels conveying her majesty's mails in narrow waters ought, above all other vessels, much more so than those navigating open seas and distant voyages, to be furnished with one at least of the best description of compasses; and why? because if we 'make out' a buoy, or light, or any known object, we steer by the compass to pick up the next buoy, for we cannot see any marks to guide us; and hence, if the compass be wrong we may lose the ship.

"I have known one of our packets at anchor more than twenty hours off the port of Liverpool, and so of the Company's boats, because they could not 'make' the lightship.

"Several of the City of Dublin packets have been on shore to the north of Dublin Bay about Malahyde, owing, I conceive, to errors in their compasses, and I myself was not fifty yards from Ireland's Eye when I supposed myself in a line with the Kish in this vessel; fortunately the engines were stopped, and I was sounding.

"I will now take leave just to mention, that on my passage from Liverpool to the Thames last December, I found that the courses steered took me to the southward, in spite of all allowance, when her head was westerly or easterly. From the Milford Islands to the Land's End I thought there was very little error; but as soon as I shaped a course up the Channel with a strong S.W. by S. gale and a heavy sea upon the quarter, I expected to find myself thrown rather upon the English shore: but no, the contrary was the fact, for, on passing headlands or lights, I found the ship several miles further off than I expected.

"I am, Sir, your most obedient servant,
"JOHN EMERSON, Master commanding.
"*Captain Johnson, R.N. &c. &c.*"

According to the directions of the Lords Commissioners of the Admiralty the Urgent was supplied with a standard compass, and was swung at Greenhithe, when the deviations upon each point were duly ascertained.

For the reasons before stated, the letter of the commander, after he had had experience of the system adopted, is here inserted:—

"*H.M. Steam-vessel Urgent, Liverpool,* 1*st January,* 1844.

"Dear Sir,

"In forwarding the report of the standard compass to the Board, I also beg to express to you the easement of mind I have derived since the compass has been on board, as by applying the difference to the binnacle compass as marked in your Deviation Table of Standard Compass, I have been enabled to run with the greatest confidence in fogs from one object to another, not only on this station, where you know I have been so long, and which to me is like A, B, C, but the same accuracy was observed on my passage from Woolwich to Pembroke and back to Woolwich with a steamer in tow; again from

Woolwich to Plymouth, and from thence up the Bristol Channel to Swansea with troops. These troops being required with all possible despatch, I actually ran the Urgent in a fog, inside the Mumbles Light to the Green Bank, before I got a pilot. The ship was in harbour in ten minutes after I received him. I had not been at this place before, and I arrived in the night.

"Again, from the Milford Islands to Liverpool we had a dense fog; my confidence in the excellence of the compass was great, and I ran for the Bell buoy and made it to a fraction, and into the Mersey, when the sailing packet of that morning was detained four hours in consequence of the fog.

"I fear I have tired you; but I beg to observe that I have not mentioned these circumstances by way of credit to myself, but to point out to you the accuracy and excellence of the compass, at the same time to express my thanks to you for having procured me the same.

"I remain, dear Sir,
"Yours very obliged and faithfully,
"JOHN EMERSON.

"*Captain Johnson, R.N. &c. &c.*"

Thus, then, from the testimony of these officers, who have had such enlarged practice in navigating steam-vessels, independently of the reiterated observations of experienced pilots to the same effect, it is evident that the remarks upon the Superb are equally applicable to the Merlin, Urgent, and Sirius, and from the numerical results of *deviations* already ascertained under my superintendence on board more than a hundred of her majesty's ships, fifty of which are steam-vessels, it may fairly be inferred that the following remarks are more or less applicable to all, viz.:—

That in all vessels where the *deviation* has not been ascertained, the courses steered by compass are not the correct magnetic courses, or those inserted as such in charts and sailing directions; consequently, in such vessels a course cannot be accurately shaped from port to port, nor even from buoy to buoy.*

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* Except only when that course happens to be one of the two points of *no deviation;* and the same as relates to bearings.

That the bearings taken by compass of lights or landmarks are not the correct magnetic bearings, or those mentioned as such in the charts or sailing directions, to keep vessels clear of rocks or shoals; and, therefore, ships, in which the *deviation* is great, but unattended to, would, undoubtedly, be run upon the said dangers, by bringing a light or landmark on the identical bearing (but by the compass on board) which was given upon the chart as that which would lead clear of them. This would unquestionably be the case when steering into a harbour, or through a narrow channel, by the compass-bearing of one object only, as in the case of the Ethalion, in the Gulf of Finland; and it is equally clear that in ships, where the deviation is not known, it would be impossible to bring two lights or marks in a line, *on the correct magnetic bearing given on the charts,* except only when the ship's head happened to be upon one of the points of *no deviation.**

Not to enlarge too much upon the subject, let us now take as examples the *deviations* of the compass ascertained on board fifteen out of the fifty of her majesty's steam-vessels (see Table I.), and referring to the accompanying chart, observe what would inevitably be the result if the vessels named in the diagrams were placed in the positions there pointed out, and steered for the mouth of the English Channel according to their respective compasses, but without their commanders having a knowledge of, or making any allowance for, *the deviation.*

The officers in command, before shaping their course, would necessarily consider how far they could depend upon their latitude and longitude; but in this case we will suppose that they had a perfect observation of the sun at noon, excellent sights for the chronometer, and also a lunar observation, and that the results of which agreeing with each other, they were morally certain of the place of their respective ships, which we shall assume to be (A, diagram 1) at the hour they shaped their course, and therefore steered on with confidence.

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* 1850. Now that all the ships of the British fleet have been swung (some of them two or three times), and the deviations ascertained, the above remarks are most fully confirmed.

According to the period of the moon, due allowance would necessarily be made for the tides; but not to embarrass the question with another source of error, let us now see what that occasioned by the deviation of the compass alone would produce.

The correct magnetic or compass course [1846] from the position A, diagram 1, latitude, 48° 0′ N., and longitude, 11° 0′ W. to the mouth of the English Channel, half way between Ushant and the Scilly Islands, is E. ¾ S.; consequently, ships, in which there was no *deviation*, steering that course would be, after a run of twenty-four hours only, at the rate of ten miles per hour, in the fairway between the French and English coasts; but mark what would inevitably be the result if the vessels named in the table were to be steered the same course, that is, E. ¾ S. according to their respective compasses:—The Gorgon would be among the rocks off Ushant; the Retribution and Vesuvius would be steering directly for the dangers about the Seven Isles; the Stromboli, Geyser, and Styx, would be advancing upon the "Roches Douvres;" while the Terrible, Penelope, Sampson, and Cyclops, would be in a direction for the dangers about Jersey and Guernsey; and the Victoria and Albert, Blazer, Porcupine, Black Eagle, and Alban, from having less deviation upon that particular course, would be nearer to the fairway; but not one vessel of the *fifteen* would be in the position which the compass course, uncorrected for *deviation*, would lead their commanders to suppose themselves in.

Referring to Table, No. IV. which contains the deviations ascertained on board several iron steam-vessels, and also referring to the double lines upon the chart, it will be seen that, even in the short run of twenty-four hours, the Princess Alice, Bloodhound, Myrmidon, and Jackal, would be upon the

TABLE I. *Deviations of the Compass, ascertained by actual*

The distances of the standard compasses from the great funnels and stern guns are tabulated to identify these results, in case, at any future time, the armament or iron-work

Direction of the Ship's Head by the Standard Compass.	May 1845. *Royal Yacht Victoria and Albert.* Capt. Lord A. Fitzclarence.	May 1843. *Blazer.* Capt. Washington.	August 1844. *Porcupine.* Capt. F. Bullock.	May 1844. *Black Eagle.* Mr. Cook.	Dec. 1842. *Alban.* Mr. King.	May 1845. *Vesuvius.* Com. G.W.O. Callaghan.	Oct. 1843. *Stromboli.* Com. Hon. E. Plunkett.
N.	1° 0′ W	3° 0′ E	0° 25′ W	0° 50′ E	4° 25′ E	2° 45′ E	2° 50′ E
N. by E.	0 30 W	4 30 E	0 10 E	1 0	5 45	4 57	5 15
N.N.E.	0 10 W	5 20 E	0 45	1 40	6 15	7 30	7 45
N.E. by N.	1 9 E	5 40 E	2 15	2 20	6 25	9 0	8 45
N.E.	2 22 E	6 40 E	2 45	2 20	6 45	10 0	9 52
N.E. by E.	2 55 E	5 40 E	3 25	2 20	5 0	10 55	10 17
E.N.E.	2 33 E	5 40 E	3 25	2 10	3 45	10 40	9 50
E. by N.	2 29 E	4 20 E	3 25	1 40	3 35	9 55	9 5
E.	2 50 E	3 40 E	3 5	1 40	2 55	8 50	7 50
E. by S.	2 30 E	2 20 E	2 35	1 10	2 35	7 15	6 25
E.S.E.	2 10 E	1 0 E	2 25	0 40	1 5	5 35	4 47
S.E. by E.	2 0 E	0 20 W	1 45	0 20	0 25 E	3 40	3 21
S.E.	2 15 E	0 50 W	1 25	0 15	1 29 W	1 50	1 55
S.E. by S.	1 45 E	1 40 W	1 10	0 10	3 14	0 20 E	0 20 E
S.S.E.	1 30 E	3 0 W	1 5	0 10 E	3 31	0 56 W	1 15 W
S. by E.	1 0 E	4 0 W	0 50	0 40 W	3 0	2 20	2 20
S.	0 59 E	4 40 W	0 20 E	0 25	3 12	3 0	3 26
S. by W.	1 0 E	5 0 W	0 5 W	0 35	3 25	4 20	4 12
S.S.W.	0 30 E	5 20 W	0 25	0 40	3 33	5 0	5 5
S.W. by S.	0 15 E	5 40 W	0 35	0 40	3 5	6 7	5 40
S.W.	0 20 W	5 40 W	0 55	1 0	3 2	7 0	6 23
S.W. by W.	0 30 W	5 30 W	1 5	1 0	2 53	7 27	7 9
W.S.W.	1 0 W	6 0 W	1 45	0 50	2 55	7 50	7 30
W. by S.	1 30 W	5 30 W	1 55	0 40	2 52	8 20	8 10
W.	1 50 W	4 50 W	2 50	0 40	2 50	8 50	8 35
W. by N.	2 0 W	4 40 W	3 3	0 40	2 4	8 10	8 30
W.N.W.	3 0 W	4 0 W	3 15	0 50	1 0	6 50	8 10
N.W. by W.	2 10 W	3 20 W	2 55	1 0	1 4	5 40	7 10
N.W.	2 24 W	1 40 W	2 45	1 15	0 18 W	4 50	5 20
N.W. by N.	2 0 W	0 40 W	2 35	1 30	0 50 E	3 20	3 50
N.N.W.	1 50 W	0 20 E	1 55	0 55 W	1 55	1 40 W	1 57 W
N. by W.	1 36 W	1 30 E	1 5 W	0 10 E	2 55 E	1 10 E	0 34 E
Dis. of Stand^d Compass from F. Funnel. S.G. St. Gun.	F. 64 ft.	F. 33	F. 35	F. 50	F.	F. 37·0 S. G. 16½	F. 36 S. G. 18

From the nature of compass observations, when different instruments and different observers are employed, some small discrepancies in the results will usually appear, as may be seen in this Table: but these, when the observations have been carefully made, will never be of such amount as to be of importance in practice; and I think the following conclusions may be fairly deduced from the results inserted in Table I.:—

1st, That in steam-vessels generally the points of no deviation are not north and south, nor are the points of maximum deviation east and west; neither does it follow that the points of no deviation, or those of maximum deviation, are invariably opposite to each other.

Observation on board Fifteen of Her Majesty's Steam-vessels.

with the dates of the observations, and likewise the names of the officers in command, in order of the vessels should be altered, so as to require them to be swung again.

Direction of the Ship's Head by the Standard Compass.	May 1842. *Geyser.* Com. E. Carpenter.	Feb. 1845. *Styx.* Com. W. W. Hornby.	Sept. 1843. *Penelope.* Commodore W. Jones.	Jan. 1843. *Gorgon.* Capt. C. Hotham.	Aug. 1845. *Cyclops.* Capt. W. F. Lapidge.	Jan. 1846. *Sampson.* Capt. Henderson	Dec. 1845. *Retribution.* Capt. S. Lushington.	May 1846. *Terrible.* Capt. W. Ramsay.
N.	2° 26′ W	2° 0′ E	0° 53′ E	1° 23′ W	2° 30′ W	1° 50′ W	4° 10′ E	0° 15′ E
N. by E.	0 31 E	4 50	2 30	0 30 E	1 10 W	0 5 E	6 20	1 5
N.N.E.	2 42	6 30	3 34	2 50	0 20 E	1 30	8 0	2 50
N.E. by N.	5 34	9 15	5 33	5 0	1 30	2 0	9 20	4 0
N.E.	6 42	9 30	7 5	7 30	3 0	2 50	10 40	4 30
N.E. by E.	7 42	10 30	7 18	9 25	4 25	3 15	12 0	5 15
E.N.E.	8 9	10 50	7 25	10 0	5 10	3 50	11 15	5 0
E. by N.	8 4	10 0	6 50	10 10	5 30	4 40	10 30	5 15
E.	7 52	7 10	6 26	10 23	5 20	5 5	9 0	4 30
E. by S.	6 12	6 0	5 40	10 40	5 0	4 10	8 0	4 20
E.S.E.	5 42	4 30	5 5	9 50	5 10	3 20	6 30	3 50
S.E. by E.	4 42	3 0	3 23	8 33	4 40	3 0	4 20	3 25
S.E.	4 0	1 31	3 20	7 19	4 20	2 45	2 0 E	2 35
S.E. by S.	3 22	1 0 E	2 3	5 17	3 30	2 30	0 20 W	2 0
S.S.E.	3 9	1 40 W	1 45	4 29	3 10	2 10	1 30	1 0
S. by E.	2 42	2 30	0 43 E	3 1	2 50	1 50	3 40	0 35 E
S.	2 4	3 20	0 2 W	1 13 E	2 10	1 0	5 0	0 30 W
S. by W.	1 39	5 25	1 42	0 32 W	1 40	0 20	6 40	1 5
S. S.W.	0 39 E	5 15	2 30	1 49	0 50 E	0 10 E	7 30	1 15
S.W. by S.	0 2 W	6 30	3 17	3 0	0 20 W	0 31 W	8 40	2 20
S.W.	1 28	6 40	4 38	5 40	2 0	1 50	9 50	3 12
S.W. by W.	2 28	7 30	5 30	7 0	2 50	2 30	10 50	3 35
W.S.W.	5 8	7 25	6 0	8 40	3 35	3 0	11 10	4 10
W. by S.	6 18	8 7	7 25	10 10	4 40	4 20	11 40	4 40
W.	7 48	9 50	8 8	12 20	6 10	5 40	11 0	5 45
W. by N.	9 20	9 0	8 35	11 18	7 0	6 40	10 30	5 40
W.N.W.	10 23	8 30	8 3	11 0	7 20	6 30	9 40	5 0
N.W. by W.	10 13	7 0	7 30	10 40	6 50	7 10	8 20	4 55
N.W.	9 43	6 25	6 57	9 47	6 40	7 0	6 40	4 50
N.W. by N.	8 36	4 50	5 35	7 50	6 25	6 10	4 30	3 55
N.N.W.	7 38	2 10	3 57	5 40	5 40	4 50	2 20 W	2 45
N. by W.	5 18 W	1 0 W	1 46 W	3 50 W	4 0 W	3 40 W	1 50 E	1 40 W
Dis. of Stand^{d} Compass from F. Funnel. S. G. St. Gun.	F. 32 S. G. 16	F. 33 S. G. 18	F. 35 S. G. 17	F. 29 S. G. 18	F. 43 S. G. 12·0	F. 46 S. G. 18	F. 52¾ S. G. 14	F. 33¾ S. G. 23¾

2dly, That the deviation in one vessel is not a guide to its amount or direction in another.

3dly, That supposing the deviations of the compass in steam-vessels to be represented by curves, they are much more abrupt in some vessels than in others, appearing as if they were produced not solely by the effect of cast-iron, such as the guns, nor by the rolled iron of the great funnel, but also by malleable iron, probably polarised, such as portions of the machinery, boats' iron davits, &c., and possibly by soft iron in certain positions.

And lastly, That nothing but actual observation in each vessel can be relied upon for practical purposes.

TABLE II. *Deviations of the Compass, ascertained by actual Experiment*

Direction of the Ship's Head by the Standard Compass.	May 1845. *Trafalgar*, 120 guns. Capt. W. F. Martin.	Sept. 1844. *St. Vincent*, 120 guns. Capt. R. F. Rowley.	May 1845. *Queen*, 110 guns. Capt. Sir B. W. Walker.	July 1845. *Hibernia*, 104 guns. Capt. P. Richards.	July 1844. *Collingwood*, 80 guns. Capt. H. Eden.	June 1845. *Superb*, 80 guns. Capt. A. L. Corry.	Feb. 1845. *Eagle*, 50 guns. Capt. G. Martin.	March 1845. *Vindictive*, 50 guns. Capt. M. Seymour.
N.	0° 5′ E	0° 10′ E	0° 10′ W	0° 5′ W	0° 10′ W	0° 17′ W	0° 8′ E	0° 5′ W
N. by E.	1 0 E	0 39 E	0 15 E	0 10 E	0 25 E	0 12 E	0 23	0 5 E
N.N.E.	1 40 E	0 58 E	0 20	0 5	0 50	0 41	0 48	0 10
N.E. by N.	2 25 E	1 1 E	0 15	0 20	1 30	1 4	0 55	0 10
N.E.	3 10 E	1 35 E	0 35	0 30	2 0	1 34	1 0	0 15
N.E. by E.	3 55 E	2 10 E	0 45	0 45	3 0	2 21	1 20	0 20
E.N.E.	4 10 E	2 30 E	1 5	1 10	3 45	2 50	1 33	0 25
E. by N.	4 10 E	2 4 E	1 10	1 25	3 50	2 [illegible]	1 38	0 55
E.	4 20 E	2 6 E	0 50	1 30	3 50	3 15	2 0	1 0
E. by S.	4 5 E	2 0 E	0 20	1 45	3 45	3 3	1 53	0 50
E.S.E.	4 25 E	1 20 E	0 20	1 15	3 30	2 51	1 40	0 45
S.E. by E.	3 25 E	1 18 E	0 10 E	1 20	3 25	2 45	1 30	0 45
S.E.	3 10 E	0 44 E	0 0	1 0	2 40	2 30	1 12	0 40
S.E. by S.	1 20 E	0 40 E	0 0	0 50	2 30	2 5	1 2	0 35
S.S.E.	0 40 E	0 30 E	0 40 W	0 30	2 0	1 25	1 1	0 30
S. by E.	0 30 E	0 10 E	0 40	0 20	1 30	0 45	0 30 E	0 10 E
S.	0 0	0 1 W	1 5	0 6 E	0 15 E	0 15 E	0 4 W	0 10 W
S. by W.	0 30 W	0 10 W	1 40	0 0	0 5 W	0 4 W	0 32	0 25
S.S.W.	1 25 W	0 20 W	2 25	0 25 W	1 30	0 26	1 5	0 45
S.W. by S.	2 30 W	0 40 W	2 35	0 50	1 46	1 2	1 28	1 5
S.W.	3 10 W	0 45 W	2 45	0 55	2 2	1 34	2 5	1 20
S.W. by W.	3 52 W	0 50 W	2 25	1 25	3 10	1 36	2 5	1 30
W.S.W.	4 35 W	1 30 W	2 30	1 25	3 30	2 7	2 8	1 35
W. by S.	4 40 W	1 30 W	2 50	1 30	4 0	2 39	2 6	1 20
W.	4 30 W	1 50 W	2 40	1 30	4 10	2 49	1 58	1 5
W. by N.	3 50 W	2 0 W	3 0	1 50	4 0	2 54	1 48	0 40
W.N.W.	3 35 W	1 47 W	2 30	1 40	3 50	2 39	1 25	0 35
N.W. by W.	2 40 W	1 31 W	2 20	1 40	3 40	2 28	1 7	0 25
N.W.	1 55 W	1 20 W	2 5	1 35	3 0	2 18	0 58	0 10
N.W. by N.	1 50 W	1 0 W	1 55	0 55	2 40	1 51	0 35	0 10
N.N.W.	1 15 W	0 27 W	1 0	0 45	2 0	1 25	0 20	0 10
N. by W.	0 40 W	0 9 W	0 50 W	0 15 W	1 20 W	0 51 W	0 11 E	0 8 W

In the ships of the line the standard compass was placed at the break of the poop, and was from sixteen to eighteen feet distant from the nearest gun; in the frigates the distance was from fourteen to sixteen feet: in the corvettes and brigs, from eleven to fourteen; and in the Erebus and Terror the steam machinery was nearly twenty feet distant from the standard compass.

The results contained in Table II. show that when the standard compass is properly placed and the iron-work removed from its vicinity, the deviations are reduced within moderate limits; but that the deviation in one ship-of-war is not a guide to its amount in another; and that, as in the case of the steam-vessels, nothing but the results of actual experiment in each ship should be depended upon.

on board Fifteen of Her Majesty's Ships-of-war of different Rates.

Direction of the Ship's Head by the Standard Compass.	June 1845. *Vernon,* 50 guns. Capt. J. C. Fitzgerald.	Jan. 1845. *Amazon,* 19 guns. Capt. Jas. Stopford.	April 1843. *Curaçoa,* 24 guns. Capt. Sir T. S. Pasley.	Jan. 1846. *Nimrod,* 20 guns. Com. J. R. Dacres.	Feb. 1845. *Fantôme,* 16 guns. Com. Sir F. Nicolson.	May 1845. *Erebus.* Disc. Ship. St. Eng. on bd. Capt. Sir J. Franklin.	May 1845. *Terror.* Disc. Ship. St. Eng. on bd. Capt. F. R. M. Crozier.
N.	0° 52′ W	0° 10′ E	0° 7′ W	0° 30′ E	0° 15′ W	0° 25′ E	0° 42′ E
N. by E.	0 18 E	0 10 W	0 13 E	0 30	0 40 E	1 30	1 55
N.N.E.	0 48	0 15	0 26	0 50	1 20	2 35	3 10
N.E. by N.	1 18	0 40	0 24	1 30	2 0	3 35	4 10
N.E.	2 0	0 40	0 43	2 0	3 5	4 15	4 50
N.E. by E.	2 42	0 50	1 5	2 40	3 18	4 45	5 20
E.N.E.	2 41	0 55	1 27	3 20	3 31	5 15	5 5
E. by N.	3 36	1 0	1 21	4 12	3 44	4 50	5 5
E.	4 32	0 50	1 40	4 40	4 0	4 55	4 57
E. by S.	4 5	0 50	1 26	4 0	3 27	4 0	4 0
E.S.E.	4 0	0 45	1 39	3 30	3 54	3 20	3 25
S.E. by E.	3 20	0 40	1 41	3 10	2 21	2 35	2 15
S.E.	2 30	0 38	1 29	2 50	1 48	1 45	2 2
S.E. by S.	1 43	0 25	1 6	2 0	1 15	1 0	0 50
S.S.E.	0 55	0 20	0 55	1 20	0 42	0 15 E	0 40 E
S. by E.	0 2 E	0 10 W	0 43	0 36	0 9 E	0 15 W	0 10 W
S.	0 54 W	0 20 E	0 32	0 30 E	0 30 W	1 0	0 50
S. by W.	1 35	0 31	0 19 E	0 30 W	1 9	1 20	1 20
S.S.W.	2 32	0 50	0 37 W	1 0	1 48	2 5	1 55
S.W. by S.	3 30	1 0	0 47	1 30	2 27	2 20	2 50
S.W.	4 25	1 30	1 7	2 0	3 8	3 5	3 15
S.W. by W.	4 41	1 33	1 12	2 25	2 23	3 35	3 55
W.S.W.	5 10	1 31	1 17	3 10	3 38	3 35	4 20
W. by S.	4 54	1 45	1 42	3 35	3 43	4 5	4 30
W.	4 57	1 45	1 33	4 0	4 10	4 0	4 20
W. by N.	5 0	1 55	1 29	3 30	4 4	4 5	4 30
W.N.W.	4 56	1 50	1 22	3 0	3 58	3 50	4 20
N.W. by W.	4 6	1 20	1 27	2 30	3 52	3 45	3 15
N.W.	3 34	0 50	1 10	2 5	3 45	3 0	3 5
N.W. by N.	3 2	0 35	1 2	1 30	2 45	1 50	1 55
N.N.W.	2 5	0 20	1 3	1 5	1 45	0 40	0 58 W
N. by W.	1 25 W	0 15 E	0 39 W	0 40 W	1 0 W	0 25 W	0 10 E

From the peculiarity occasionally observable in some of the deviations, it appears probable that these are attributable to the magnetic influences of malleable iron, such as the boats' davits, &c.

In the case of the Amazon it will be seen that the deviations of the standard compass upon the poop were reversed in direction to that which usually obtains, evincing that the iron rails and davits abaft had a more powerful influence upon the compass than the ship's guns forward.

TABLE IV. *Deviations of the Compass, ascertained*

Direction of the Ship's Head by the Standard Compass.	1844. *Princess Alice.* L. Smithett, Esq.	1844. *Dover.* E. Lyne, Esq.	March 1845. 1st Position. *Jackall.* J. Henderson, Esq.	July 1845. 2d Position. *Jackall.* Lt. Pasco.	1845. *Bloodhound.* Lt. Phillips.	1845. *Lizard.* Lt. Tylden.
N.	1° 46′ E ○	4° 8′ W	0° 20′ E ○	2° 15′ W	1° 0′ W ○	1° 37′ W
N. by E.	4 49 E	2 20 W	7 20	2 40 E ○	3 20 E	2 50 E ○
N. N. E.	9 20 E	3 0 W	14 40	8 58	7 15	6 30
N. E. by N.	11 40 E	2 50 W	22 20	13 7	10 50	9 50
N. E.	14 38 E	4 0 W	22 40	15 18	13 20	11 20
N. E. by E.	15 25 E	5 0 W	25 0	17 15	14 40	13 5
E. N. E.	15 41 E	4 36 W *	24 20	18 7 *	15 0	14 5 *
E. by N.	15 40 E *	4 40 W	25 30 *	17 47	15 0 *	13 25
E.	14 30 E	5 50 W	23 40	15 35	14 0	12 45
E. by S.	12 40 E	6 20 W	21 10	14 38	13 20	11 5
E. S. E.	11 30 E	5 45 W	18 40	13 22	11 50	9 32
S. E. by E.	9 8 E	4 45 W	14 50	11 40	10 20	9 0
S. E.	8 25 E	4 8 W	11 44	9 55	9 20	7 10
S. E. by S.	5 58 E	3 40 W	7 50	8 5	7 50	6 0
S. S. E.	4 15 E	2 0 E ○	4 40	5 35	6 20	4 47
S. by E.	2 0 E	2 20 E	1 30 E	4 12	4 20	3 45
S.	0 10 W ○	6 0 E	2 0 W ○	2 20 E	2 40	2 40
S. by W.	2 16 W	8 10 E	4 40	0 12 W ○	1 20 E	2 2 E
S. S. W.	4 10 W	9 50 E	7 0	2 32	0 50 W ○	0 32 W ○
S. W. by S.	5 40 W	11 30 E	11 10	4 55	2 40	2 42
S. W.	7 35 W	11 30 E	14 0	6 30	5 20	4 52
S. W. by W.	9 30 W	12 5 E *	16 30	8 45	7 10	7 15
W. S. W.	11 20 W	11 5 E	18 40	10 52	9 50	9 25
W. by S.	13 4 W	10 5 E	21 30	13 50	11 10	11 32
W.	14 27 W	7 40 E	24 0	15 45	13 0	13 40
W. by N.	15 20 W *	6 15 E	25 0 *	17 25	15 50	15 35
W. N. W.	14 50 W	4 0 E	24 40	18 25	16 40 *	16 15
N. W. by W.	14 25 W	1 55 E	24 0	18 25 *	16 30	16 15 *
N. W.	13 8 W	1 40 E	21 30	17 15	15 30	15 45
N. W. by N.	10 30 W	0 20 W ○	18 0	15 45	13 30	13 15
N. N. W.	8 40 W	1 25 W	15 30	11 55	11 20	9 20
N. by W.	4 40 W	2 46 W	6 30 W	7 25 W	6 0 W	5 57 W
Dis. of Stand^d Compass from F. Funnel. S.G. St. Gun.	F.	F.	F. 25½	F. 42¼	F. 41½	F. 41¾

* The asterisk denotes the points of ***maximum deviation***, and the ○ the points of ***no deviation.***

It will be seen by the above results, that the deviations ascertained in one iron vessel are not a guide to their ***amount*** or ***direction*** in another.

The great differences of the deviations in some of the above-named vessels may, to a certain extent, be attributable to the difference in their construction, some of them having iron beams and others wood; but here, as in timber-built ships, it is quite cer-

on board Eleven of Her Majesty's Iron *Steam-vessels.*

Direction of the Ship's Head by the Standard Compass.	1846. *Harpy.* Lt. Proctor.	1846. *Torch.* Lt. Hoseason.	1844. *Dwarf.* Lt. Nicolls.	1846. *Onyx.* Lt. Mudge.	1846. *Violet.* Lt. Sherlock.
N.	2° 40′ W	4° 35′ W	3° 40′ W	4° 0′ W	6° 10′ W
N. by E.	0 50 W ○	1 0 W ○	0 20 E ○	4 30	3 45 W
N. N. E.	1 50 E	2 30 E	3 45	4 50	0 15 W ○
N.E. by N.	4 20	4 42	5 52	5 30	3 45 E
N. E.	5 30	7 25	8 30	5 0	5 40
N.E. by E.	6 10	9 35	10 30	5 30	7 10
E. N. E.	6 10	10 22	11 50	6 40	8 30
E. by N.	6 10 *	11 0 *	12 10	7 40	8 40 *
E.	5 10	10 30	12 32	8 30	8 20
E. by S.	5 40	10 10	12 40 *	9 0 *	8 14
E. S. E.	4 35	9 5	11 5	8 50	8 0
S. E. by E.	4 0	8 0	10 45	8 0	7 55
S. E.	3 55	7 35	9 25	7 0	7 25
S. E. by S.	3 40	6 40	8 0	4 30	6 55
S. S. E.	2 50	5 45	6 0	2 0 W	6 52
S. by E.	3 0	4 50	5 5	2 0 E ○	6 38
S.	3 35	3 40	3 5	5 0	5 55
S. by W.	3 5	2 37	0 50 E ○	6 45	5 45
S. S. W.	1 55	1 0 E	1 15 W	9 45	3 50
S.W. by S.	0 45 E	0 30 W ○	3 10	11 40	2 32
S.W.	0 0 ○	2 40	5 58	11 35	0 10 E ○
S.W. by W.	2 10 W	5 8	8 10	12 10 *	2 18 W
W. S. W.	3 40	7 13	10 32	10 50	3 48
W. by S.	6 5	9 10	13 20	9 10	5 58
W.	7 30	11 13	14 13	7 5	7 50
W. by N.	8 40	12 40	15 45 *	5 10	9 38
W. N. W.	10 40 *	14 13	15 30	2 40	10 35
N.W. by W.	10 5	14 43	15 25	0 30 E ○	12 57
N. W.	10 0	14 48 *	14 30	1 10 W	12 40
N.W. by N.	8 20	12 50	12 0	2 40	13 0 *
N. N. W.	7 25	10 10	9 55	3 50	11 20
N. by W.	5 30 W	8 30 W	6 55 W	4 0 W	9 40 W
Dis. of Stand^d Compass from F. Funnel. S. G. St. Gun.	F. 46	F. 42½	F. 32¾	F. 19	F. 23

tain that nothing but actual experiment on board each vessel can be relied upon for practical purposes.

The two series of observations in the Jackall show the great difference of amount of deviation when the compass is placed in different positions, and for the difference of bearing of a distant object caused by a yet greater alteration of position. See page 34.

French coast, to the *southward* of Ushant, while the Dover and Onyx would be steering towards the Lizard; thus spreading the angle of the deviations over the entire space of ocean between France and England, and that, too, in a run of twenty-four hours only, and in vessels where the greatest care was taken in elevating and placing the compasses, and also in removing all iron-work from their immediate vicinity.

Although the placing compasses in iron ships will be noticed in a separate part of this work, yet, to show the utter impossibility of navigating them without the most systematic and constant precaution, one fact in proof thereof may be mentioned in this place, viz., that when the Onyx's head was at north (correct magnetic) the binnacle compass in front of the wheel indicated it to be S.E.!! Before proceeding to comment upon the next diagram, it will be essential to peruse Table, No. II. in which the deviations of the compass ascertained on board different classes of her majesty's ships, from those of the line mounting 120 and 80 guns to frigates of 50, corvettes of 20 and sloops of 16 guns, are inserted; and then refer to the dotted lines upon the chart for their illustration.

Let us now suppose the distance of this fleet, accompanied by the steam-vessels, to have been double that which was represented in diagram, No. 1, or, in other words, forty-eight hours' run, instead of twenty-four (and there is assuredly nothing improbable in assuming forty-eight continuous hours of thick weather often to prevail in our humid climate), and the result would be, that the course, E. ¾ S., according to their respective compasses, would lead some of the sailing-ships towards the French coast: the Penelope, Styx, Stromboli, Vesuvius, and Retribution, far to the southward of Ushant; the Gorgon to the south part of Hodierna Bay; while the iron steamers, Princess Alice, Bloodhound, and Myrmidon, would be as far *south* as Quiberon; the Dover, as far *north* as the Scilly Islands—in short, running directly for them; and the Onyx actually passing them, yet further to the north, and steering in a direction for the Bristol Channel.

Be it observed, that the above reasoning obtains from the results ascertained with standard compasses carefully placed in the midship line of the different vessels, and as far removed as was practicable from iron-work likely to affect their magnetic needles;* and it is, therefore, probable that vessels navigated with binnacle compasses only would have the errors increased by reason of their nearer proximity to the guns and iron-work.

The lines in diagram 2 show the divergency of each vessel when steered a compass course, uncorrected for *deviation,* by which the general tendency of ships to be drawn to the southward of their reckoning, when coming up Channel, is palpably demonstrated; the only exceptions being those of the Onyx and Dover iron steam-vessels, and the Amazon, the iron-work about the poop of the latter vessel having overcome the effect of the guns forward.

By this diagram it will be seen that some of the vessels, having large deviations, would be involved among the dangers and intricacies of the Channel Islands in less than the short period of twelve hours; and pursuing the track of the others higher up, one cannot help remarking how easily mistakes may be made, and how vessels may be brought upon the coast of France, in such a way as to puzzle those in command as to the lights seen; and this, not only by reason of the deviations of the compass, but also when approaching the narrower part of the Channel, from the proper distance having been overrun before the vessel's course was changed.

Diagram 3 represents the courses of the same vessels when steered to the westward from a position off Dungeness; by which also the general tendency of ships, being to the *southward* of their reckoning in these latitudes while steering down Channel, is clearly developed. In this case, even in twelve hours' run, the Gorgon and Retribution would not clear Cape La Hogue, while the Penelope, Sampson, Cyclops, Geyser, Styx, and Vesuvius, would be run among the dangers about the Islands of Alderney and Guernsey. The exceptions being in this, as in the former case, the two iron vessels.

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* See copy of Regulations at the conclusion.

The diverging lines in diagram 4 show the course of all the vessels when steered for Milford Haven, according to their respective compasses uncorrected for *deviation;* by which it will be seen that, in the course of twenty-four hours, some of them would be passing up the Bristol Channel and others up St. George's Channel, but not one would be precisely in the place anticipated by her commander: indeed, the Gorgon, Vesuvius, and Stromboli, would be in the vicinity of Lundy Island, the Bloodhound and Princess Alice on thecoast of Cornwall, and the Onyx upon the coast of Ireland.

The lines in diagram 5 show the serious results which would occur in the short run of these vessels from Milford Haven to the Scilly Islands.

Should a course have been shaped to pass to the westward of the islands, then the Retribution, when running that course according to her compass uncorrected for deviation, would strike the Seven Stones between Scilly and the mainland; the Vesuvius, Styx, Gorgon, and Stromboli, would be steering for the centre of the group of islands; the Trafalgar, Vernon, Penelope, and Blazer, would strike the outer dangers; while the iron steamer Jackal (having her compass in the first position) would be run for the Longships, and the Onyx and Dover would pass out into the Atlantic, far to the westward of Scilly, and out of sight of land.

A glance at the charts and sailing directions for the more intricate channels of our own coasts (see those of the Severn, Bristol Channel, Mersey, Downs, &c.), where it frequently happens that the compass courses are the only guides, will prove how indispensable it is that these should be accurately steered. Take, for instance, the following passage from the "Sailing Directions for the North Sea," page 13:—

> "In coming from sea, &c., ships must not bring the north Sand Head (or Goodwin) Light to the eastward of S.E. until the Gull Stream Light bears S.W. ¼ S. and the North Foreland N.N.W. ½ W. They will then have the Gull Stream open, and by steering S.W. ½ W. until they bring the Gull Light E.N.E. they may then steer W.S.W. for an in-shore berth in the Downs, or keep on a S.W. ½ W. course for a man-of-war's roadstead.
>
> "Particular care and attention must be observed in taking the above bearings, and in the steerage of ships, as the angles are small and the channel narrow."

Here, then, we have an instance where the bearings and compass courses are the only guides; but of what avail would these cautious directions be in vessels wherein not one bearing could be observed accurately, nor one course steered correctly, by reason of the deviation of the compass? The serious results to be apprehended are too obvious to need any comment.

Again, let us suppose that the fifteen vessels named in the Table were driven by stress of weather to seek shelter in a port such as is represented in the working diagram No. 7, and that the "Sailing Directions" for the said port stated—

> "That as there were not two objects upon the neighbouring land sufficiently distinct which could be used as a safe leading mark between the dangers, the only resource was to bring the church at the west-end of the harbour to bear very exactly W.S.W. by compass, and steer in with it upon that bearing, which would lead in mid-channel between the Sunken Rocks on the north and the shoal on the south side of the entrance."

By turning the north point of the compass-card to the left (as explained in the working diagram) till it corresponds with the amount of deviation ascertained on board these vessels when their heads were towards the W.S.W., or, to take a single case, by drawing a parallel line PPL to that bearing indicated by a ship's compass having half a point westerly deviation, the position of such a vessel, when the church would bear W.S.W. by her compass, will be seen, and from which it is evident that eleven of the fifteen vessels formerly alluded to, steering in with the church bearing W.S.W. by their respective compasses (affected by the iron) would be run upon the Sunken Rocks at the entrance; while the Table of Deviations ascertained on board the iron steam-vessels shows that, under such circumstances, they would be yet wider of their mark, and that some of them would even be run upon the shoal to the south of the entrance, by reason of their deviations being in an opposite direction.

Let us now conceive another case. Imagine a commodious inlet to the southward of the larger harbour, offering good anchorage; but which, in consequence of its very narrow entrance, had two beacons erected, and these, according to the "Sailing Directions," "were to be brought in one, bearing S.W. by S. by compass, and the anchorage be attained by running in with them upon that bearing."

Each vessel, according to her position, would be manœuvred with the view of bringing the beacons in one, bearing S.W. by S., before the entrance was attempted; but not one would be enabled to accomplish this, except only when the vessel's head happened to be upon one of the points of no deviation; and when again the course was directed to the S.W. by S. for the purpose of running into the inlet, the vessel's head would no longer be found pointing in the direction of the beacons; and hence the most unjust and perplexing suspicions as to the accuracy of the charts would arise, and which might lead to the most disastrous consequences.

Compass Observations on board Iron Steam-vessels.

With respect to the Table of Deviations (see No. 4 and Supplement) ascertained on board several of her majesty's iron steam-vessels, it may be proper to remark that the plan hitherto pursued has been that recommended by the Compass Committee at paragraph 12 of the "Practical Rules" (see copy at the conclusion), viz. to elevate the standard compass more than is necessary or convenient in other vessels, ascertain the deviations upon each point, and treat the question in other respects similarly as in timber-built ships.

By thus elevating the compass in the centre line of each iron ship, and ascertaining by actual experiment on board a position more or less forward or aft on the quarter-deck, where the deviations are reduced within moderate limits, the process, so far, has answered well in practice; but much information may yet be expected from the results of experience on this subject in different regions and under different circumstances.

In small iron vessels, particularly those propelled by the screw, some difficulty has occurred respecting the augmentation of motion when the compass is elevated; there is little doubt, however, but that this difficulty will be overcome by some of the contrivances of different individuals now in progress of trial.

To show how worse than useless a compass would be on board an iron ship without great care and judgment in placing it, and ascertaining the deviations according to the Committee's plan, or without the process of correction according to that of the Astronomer Royal, I may here refer to Tables, Nos. IV. and VIII., and also to the remarkable fact already noticed on board the Onyx.

The Table, No. VIII. of deviations of the compass, when placed in different parts of an iron ship, may also be useful to prove that no reliance whatever can be placed upon bearings taken from different positions on board, until the deviations shall have been ascertained. The advantage of elevating the compass is likewise made apparent by these results; but further remarks respecting them may be found in a paper by the author of this work, printed in the "Philosophical Transactions" for 1836.*

With respect to the ingenious plan of the Astronomer Royal for correcting the deviations of the compass on board iron-built ships by means of magnets, &c. (see "Phil. Trans." 1839), in numerous cases upon our own coasts, it is represented to have worked well; in some others, however, the contrary is stated to have taken place.

Whether this may have been owing to any alteration in the magnetism of the vessels themselves, or in the correcting magnets, or from some defect in the arrangements made by the persons placing the correcters, it is difficult to say; but the subject is of that great importance that a more enlarged experience of it, in unison with the Committee's plan of elevating the compass, as already described, is very desirable: so that, by having good instruments systematically placed upon both plans on board the same ship, and tried in different regions by competent officers, a more just estimate of the merits of each plan may be arrived at, particularly as respects the permanency of the correction in the one case and the amount of error in the other. In concluding these remarks, I must observe that I am fully assured that both the Astronomer Royal and also the members of the Compass Committee are equally anxious that every proper test should be applied.†

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* The same paper contains the first notice of effects indicating the presence of permanent magnetism in iron vessels, which effects were distinctly elicited by their action upon magnetic instruments, even at the distance of 189 feet.

† 1850. I must not omit to mention the ingenious plan of an unequally graduated card corrected for the deviations of the iron steam-vessel Myrmidon, with which Capt. J. S. Sparkes favoured me some years ago.

Capt. A. Milne, R.N. (now one of the Lords of the Admiralty), likewise constructed a card of this kind as far back as 1832: but the objections to the employment of such cards are the changes in the deviation from whatever cause produced, but more particularly from the changes in the ship's geographical position.

TABLE VIII.

Showing the Amount of Deviation of Compasses placed in different parts of an Iron Vessel.

Further particulars respecting these Deviations may be seen in the "Philosophical Transactions for 1836."

Correct Magnetic Direction of Ship's Head.	Place of the Compasses.					
	Binnacle Compass in its ordinary place in front of the wheel.	A stage projecting four feet over the stern.	Inside of an iron sphere near the centre of the vessel, seven feet above the deck.	The after-part of a temporary poop, eight feet above the rudder head.	The fore-part of a temporary poop, 8½ feet above the deck.	A stage near the gaff, 20½ feet above the deck.
N.	13° 30′	2° 0′	7° 30′	1° 15′	4° 45′	0° 15′
N. by E.	16 45	6 5	3 45	1 15	5 45	0 30
N.N.E.	not observed.	11 30	0 0	6 0	5 0	1 0
N.E. by N.		16 15	2 15	8 15	5 45	0 45
N.E.	16 30	19 55	4 0	10 40	6 0	3 0
N.E. by E.	19 45	23 45	6 15	13 15	5 45	2 15
E.N.E.	19 30	29 30	7 30	15 0	7 0	2 30
E. by N.	19 15	32 15	11 45	16 45	4 30	4 25
E.	19 0	34 30	14 0	17 45	7 15	2 30
E. by S.	16 45	13 45	13 15	16 15	7 45	2 15
E.S.E.	not observed.	7 0	16 30	17 0	7 0	3 45
S.E. by E.		27 45	15 45	16 15	9 45	2 15
S.E.	3 0	38 30	18 0	14 0	4 30	2 0
S.E. by S.	not observed.	23 21	16 15	12 15	2 45	2 0
S.S.E.		30 36	15 30	10 30	0 30	0 30
S. by E.		21 45	13 45	8 45	2 35	0 0
S.	9 0	4 0	11 0	3 45	2 30	2 0
S. by W.	11 15	10 15	11 15	0 45	4 25	0 15
S.S.W.	16 30	20 0	7 0	3 0	5 30	0 30
S.W. by S.	19 45	29 15	3 45	6 45	7 45	1 15
S.W.	23 30	32 0	1 20	9 10	9 15	0 30
S.W. by W.	22 15	34 15	9 45	12 45	8 15	1 45
W.S.W.	26 30	34 30	11 30	14 30	8 30	0 50
W. by S.	27 45	33 15	16 15	16 45	7 15	2 15
W.	30 0	31 0	22 55	17 0	6 15	1 0
W. by N.	24 15	28 45	23 45	17 5	4 45	3 45
W.N.W.	24 30	26 0	24 0	17 0	1 0	0 30
N.W. by W.	22 45	21 15	22 15	14 35	0 15	2 15
N.W.	10 30	17 45	22 45	12 30	2 15	2 30
N.W. by N.	7 15	13 45	17 45	10 15	3 15	2 45
N.N.W.	10 30	9 30	16 0	8 0	5 0	2 0
N. by W.	9 15	5 0	12 15	5 45	1 45	0 45

These results prove that no dependence whatever can be placed upon the bearings or courses in any iron ship until the deviations of the compass shall have been ascertained; and they also show the advantage of elevating the compass, by which the deviations are considerably reduced.

Since the first edition of this work was printed, every fact elicited by experience in compass matters has confirmed what has already been said as to the necessity for constant and multiplied observations under all circumstances, and that the results on board one ship are no guide to the *amount* or *direction* of the deviations in another.

In some iron ships it appears that the deviations of a compass when considerably elevated are not subject to so much change (while the ship remains in or near the same geographical position) as to make them of importance in practice, while in others the same remark does not seem to apply; hence one of the many arguments in favour of constant observation.

The following Table exhibits the deviations of H. M. iron steam-frigate Birkenhead, which has been swung four times by different officers, viz. once by Commander Strange, once by Mr. Thompson, and twice by myself, at different periods; and the next Table to that shows the results obtained on board the Onyx under different circumstances, and which vessel, it will be remembered, was proved to have remarkably powerful magnetic influences abaft. See page 27.

SUPPLEMENT TO TABLE IV.

Showing the Deviations of the Standard Compass of H. M. Iron Steam-frigate Birkenhead, at different periods.

NOTE.—The Compass was placed near the break of the poop, which was supported by wooden beams, the card being 11 feet 2 inches above the level of the iron "top sides" of the ship.

Direction of Ship's Head by Standard Compass.	Greenhithe, 1847. Observer, Capt. Johnson.	Portsmouth, 1847. Observer, Comdr. Strange.	Portsmouth, 1848. Observer, Capt. Johnson.	Portsmouth, 1850. Observer, Mr. Thompson.
	Deviation of Standard Compass.	Deviation of Standard Compass.	Deviation of Standard Compass.	Deviation of Standard Compass.
North.	6° 35 W.	6° 40′ W.	7° 18′ W.	7° 10′ W.
N. by E.	7 40 W.	8 10 W.	8 56 W.	9 0 W.
N.N.E.	9 25 W.	9 20 W.	10 9 W.	10 20 W.
N.E. by N.	9 50 W.	10 40 W.	11 26 W.	11 40 W.
N.E.	11 25 W.	12 20 W.	12 20 W.	12 30 W.
N.E. by E.	13 25 W.	13 20 W.	13 49 W.	13 50 W.
E.N.E.	12 30 W.	13 30 W.	14 2 W.	13 50 W.
E. by N.	12 45 W.	14 30 W.	14 15 W.	13 30 W.
East.	12 30 W.	14 40 W.	14 40 W.	15 40 W.
E. by S.	12 0 W.	13 40 W.	13 39 W.	14 10 W.
E.S.E.	12 20 W.	12 20 W.	12 53 W.	11 50 W.
S.E. by E.	10 0 W.	11 40 W.	10 53 W.	10 10 W.
S.E.	8 20 W.	8 30 W.	8 0 W.	7 0 W.
S.E. by S.	3 50 W.	6 0 W.	5 24 W.	5 10 W.
S.S.E.	○1 30 W.	○1 30 W.	○1 50 W.	○1 0 W.
S. by E.	2 50 E.	2 20 E.	3 12 E.	2 50 E.
South.	7 0 E.	7 20 E.	6 54 E.	6 50 E.
S. by W.	12 35 E.	10 50 E.	11 0 E.	10 40 E.
S.S.W.	13 45 E.	13 40 E.	13 21 E.	12 50 E.
S.W. by S.	16 40 E.	16 0 E.	15 42 E.	15 30 E.
S.W.	18 5 E.	17 10 E.	17 3 E.	16 10 E.
S.W. by W.	18 10 E.	16 40 E.	17 22 E.	17 40 E.
W.S.W.	16 45 E.	16 30 E.	16 30 E.	16 20 E.
W. by S.	15 40 E.	15 20 E.	15 16 E.	15 0 E.
West.	13 50 E.	12 20 E.	12 46 E.	12 10 E.
W. by N.	11 45 E.	11 40 E.	10 36 E.	10 0 E.
W.N.W.	9 40 E.	8 30 E.	7 54 E.	7 50 E.
N.W. by W.	5 35 E.	5 30 E.	5 12 E.	5 10 E.
N.W.	2 20 E.	2 30 E.	2 30 E.	2 30 E.
N.W. by N.	○0 15 W.	○0 10 W.	○1 9 W.	○1 20 W.
N.N.W.	2 0 W.	3 0 W.	3 25 W.	3 30 W.
N. by W.	4 50 W.	5 0 W.	5 41 W.	4 20 W.

○ Points of no deviation.

SUPPLEMENT TO TABLE IV.

Showing the Deviations of the Standard Compass of H. M. Iron Steam-packet Onyx, observed under different circumstances: — *1st, with her usual equipment; 2d, when seven additional tons of iron bars and three tons of iron machinery were on board; and 3d, after the vessel had had a thorough repair, new boilers, larger than before, a funnel of augmented diameter, new paddle-wheels, &c.; and in the last instance the Standard Compass was six inches farther forward.*

Direction of the Ship's Head by the Standard Compass.	1. Greenhithe, 1846. Vessel with her usual equipment.	2. Greenhithe, 1848. Seven additional tons of iron bars, and 3 tons of iron machinery on board.	3. Greenhithe, 1850. After a thorough repair, new boilers, funnel, &c., and the Standard Compass 6 in. farther forward.
	Deviation.	Deviation.	Deviation.
North.	4° 0′ W.	3° 10′ W.	7° 20′ W.
N. by E.	4 30 W.	2 30 W.	5 22 W.
N.N.E.	4 50 W.	3 0 W.	3 25 W.
N.E. by N.	5 30 W.	3 0 W.	1 30 W.
N.E.	5 0 W.	2 30 W.	0 20 W.
N.E. by E.	5 30 W.	3 0 W.	1 35 E.
E.N.E.	6 40 W.	3 30 W.	2 10 E.
E. by N.	7 40 W.	4 0 W.	2 0 E.
East.	8 30 W.	5 30 W.	2 40 E.
E. by S.	9 0 W.	6 0 W.	2 30 E.
E.S.E.	8 50 W.	6 50 W.	2 20 E.
S.E. by E.	8 0 W.	6 0 W.	3 30 E.
S.E.	7 0 W.	4 0 W.	5 0 E.
S.E. by S.	4 30 W.	3 0 W.	6 20 E.
S.S.E.	2 0 W.	1 10 W.	7 40 E.
S. by E.	2 0 E.	2 0 E.	8 21 E.
South.	5 0 E.	5 40 E.	9 2 E.
S. by W.	6 45 E.	6 30 E.	9 56 E.
S.S.W.	9 45 E.	9 20 E.	10 40 E.
S.W. by S.	11 40 E.	11 30 E.	9 0 E.
S.W.	11 35 E.	10 0 E.	8 20 E.
S.W. by W.	12 10 E.	9 30 E.	5 50 E.
W.S.W.	10 50 E.	9 0 E.	3 0 E.
W. by S.	9 10 E.	7 10 E.	0 20 E.
West.	7 5 E.	6 0 E.	1 25 W.
W. by N.	5 10 E.	3 30 E.	4 20 W.
W.N.W.	2 40 E.	1 30 E.	7 25 W.
N.W. by W.	0 30 E.	0 50 W.	8 50 W.
N.W.	1 10 W.	2 0 W.	10 15 W.
N.W. by N.	2 40 W.	2 40 W.	10 18 W.
N.N.W.	3 50 W.	3 10 W.	10 22 W.
N. by W.	4 0 W.	3 50 W.	8 50 W.

The very marked differences in the deviations of the Onyx demonstrate the necessity of re-swinging all such vessels whenever any alteration is made in their iron-work, or in the position of the compass with respect to it, however small that alteration may be.

When the differences in the direction of the ship's head, as indicated by the standard and binnacle compass, are very large, much inconvenience is experienced in coast navigation; I therefore reduced the deviations of the binnacle compass of the Onyx by means of magnets,* still, however, making the standard the regulating compass, as heretofore, according to the plan recommended by the Committee.

With reference to the application of magnets, the following letter from a most experienced officer, and who has commanded a large iron steam-ship for six years, is important; but whether the plan of *reducing*† the deviations by means of magnets be adopted, or that of an iron plate in the vicinity of the compass,‡ or iron bars similar to those in the ship's sides or beams be assayed for such purpose, yet the mariner's best safeguard, "constant observation," should never be neglected.

"*Steam-ship City of London: London, 5th June*, 1850.

"Sir,

"Having had six years' experience in command of the iron steam-ship City of London, of 1116 tons and 420 horses' power, during which period the vessel made 300 passages between London and Aberdeen, perhaps the following particulars relating to the compass question in iron ships might be useful to be known.

"Before starting the ship on her first voyage in 1844 we had a compass placed in front of the steering-wheel, which was corrected with a magnet about thirty inches in length by Mr. Gray, of Liverpool, and the course of the ship was regulated by that compass during sixteen months; but on 16th Nov., 1845, at 5·30 A.M. the ship took the ground on the Gunfleet Sand in the East Swin, in consequence of an error in the said compass, and I afterwards discovered that the courses steered no longer answered to those laid down on the chart and in the sailing directions for the different fairways.

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* See system of the Astronomer Royal.

† I purposely use the term *reducing* to avoid anything that would imply a certain and permanent correction under all circumstances.

‡ See plan of Professor Barlow.

"I then applied to have the compass examined by Mr. Gray, who had corrected it in the first instance; and this was done accordingly, when he found that from some cause or other the compass was incorrect, and removed the magnet and replaced it by another of larger power, when the compass was found to point truly. For about twelve or eighteen months the courses steered answered very well, but after that time I had reason to suspect there was something wrong again, the compass courses no longer leading me in the proper fairway. After consulting with you on the subject, I adopted the plan you recommended, namely, to allow the compass in front of the wheel to remain with the magnet, but at the same time to try the plan of elevating another compass very considerably, so as to reduce the deviations, and to swing the ship in order to ascertain the amount of error on each point. This I did in Aberdeen, having elevated a compass ten feet above the deck on the mizen-mast, where I found the following deviations. (*See* p. 40, Table A.)

"Since that period I have navigated the ship by the elevated compass, making at the same time, during the voyage, continual comparisons between it and the compass in front of the wheel; and the result has been that the courses steered, making due allowance for the deviations, has brought the ship in perfect safety through the different fairways.

"Having had again reason to suspect some error in the compass in front of the wheel, to which the magnet was applied, I swung the ship in March last at Aberdeen, which proved the fact of the said compass being very considerably in error, as the Table B will show.

"From the foregoing circumstances, and also from the frequent comparisons I make between the elevated compass and that to which the magnet is applied, I do not consider that the magnet properly corrects the compass for any great length of time: I think, however, that the application of magnets for reducing the otherwise large deviations of the steering compass are a useful application in coast navigation, in iron ships, when used in addition to the plan of elevating another compass as a regulator.

"I have the honour to be, Sir,
"Your most obedient humble servant,
"JOHN CARGILL.

"*Captain E. J. Johnson, R.N. Admiralty.*"

Iron Steam-ship City of London.

TABLE A.

Showing the Deviations of the Compass elevated ten feet up the mizen-mast.

TABLE B.

Showing the Deviations of the Binnacle Compass in front of the wheel, ascertained at Aberdeen, in 1850, the Magnet being in the same position as when placed in Nov. 1845.

Direction of Ship's Head by elevated Compass.	Deviation of elevated Compass.	Direction of Ship's Head by Binnacle Compass, the Magnet being still applied.	Deviation of Binnacle Compass, the Magnet being still applied.
North.	1½° W.	North.	0°
N. by E.	1 E.	N. by E.	1½ E.
N.N.E.	2¾ E.	N.N.E.	3½ W.
N.E. by N.	2½ E.	N.E. by N.	6 W.
N.E.	4½ E.	N.E.	7½ W.
N.E. by E.	5½ E.	N.E. by E.	7½ W.
E.N.E.	6 E.	E.N.E.	1½ W.
E. by N.	7½ E.	E. by N.	2½ W.
East.	7½ E.	East.	6 W.
E. by S.	6 E.	E. by S.	8 W.
E.S.E.	5½ E.	E.S.E.	6 W.
S.E. by E.	3½ E.	S.E. by E.	6 W.
S.E.	2 E.	S.E.	3½ W.
S.E. by S.	½ E.	S.E. by S.	3½ W.
S.S.E.	¼ E.	S.S.E.	4 W.
S. by E.	½ W.	S. by E.	5 W.
South.	1¾ W.	South.	2 W.
S. by W.	2¾ W.	S. by W.	1½ W.
S.S.W.	4 W.	S.S.W.	1½ W.
S.W. by S.	4½ W.	S.W. by S.	1½ W.
S.W.	5½ W.	S.W.	2 W.
S.W. by W.	7½ W.	S.W. by W.	4½ E.
W.S.W.	8¼ W.	W.S.W.	8 E.
W. by S.	9 W.	W. by S.	10 E.
West.	9 W.	West.	7½ E.
W. by N.	9½ W.	W. by N.	4 E.
W.N.W.	9¾ W.	W.N.W.	5½ E.
N.W. by W.	9½ W.	N.W. by W.	4½ E.
N.W.	9 W.	N.W.	3 E.
N.W. by N.	7½ W.	N.W. by N.	1 E.
N.N.W.	5¾ W.	N.N.W.	½ E.
N. by W.	3½ W.	N. by W.	0

Presuming that enough has now been said to convince the most sceptical person of the amount of compass errors caused by the aggregate influence of iron in ships, and of the serious consequences which must inevitably occur if the *deviations* of the compass be not ascertained and correctly allowed for, it will be proper to proceed to the second division of the subject, viz.:—

II. *On the errors produced when portions of iron work, or moveable pieces of iron, are improperly placed near the compass.*

The every-day experiment of drawing a compass-needle aside from its true direction by means of a piece of iron, might be expected to produce extreme caution against placing any portion of that metal near to an instrument of so much consequence as a ship's compass. This, however, has certainly not always been the case: whether the omission may have arisen from an erroneous notion that, where such vast masses of iron have been introduced into the art of ship-building, smaller portions of that metal placed near the compass could be of little importance, it is impossible to say; but it may be right in this place to state, that the reverse of this notion is the truth: for, wherever there is much iron in different positions about a ship's compass, the directive power of the needle is diminished, and hence, in such ships (and more particularly in iron ships), the proximity of any smaller portion of iron becomes the more baneful, because the directive power of the needle being reduced, and the attractive power of any portion of iron remaining the same, the *deviation* of such compass-needle would be thereby increased.

In the Garryowen iron steam-vessel I ascertained, by direct experiment, that there was a difference of 5° 20′ in the deviation by the mere circumstance of swinging the quarter-boat's iron davits in-board, as if for securing the boat for bad weather.

In iron ships, even, it is essential that such apparently trifling portions of iron as the wire of the skylights should be kept at a distance from the compasses.*

But to proceed with the facts. It appears by official documents that his Majesty's ship Courageux, 74 guns, Captain Wilkinson, ran upon a reef near Anholt on the night of November 13, 1812, while steering a course which, had the compass not been affected by some local influence, would have led clear of it.

By this accident, according to the Report of the surveying officers, it was found

> " That the rudder had been lost, stern-frame much shook, copper started from the stern-post, two beams on the orlop-deck badly sprung, and one pillar upset, transom-beams and sweep sprung, ship's bottom supposed to be much shook, false keel gone, &c.; and from the whole, the surveying officers reported that it was their opinion that the said ship proceeding to cross the North Sea during the winter months would be attended with extreme danger to the lives of the officers and crew."

A court-martial, it appears, was held at Chatham, May 8, 1813, on board the Courageux, on her return to England, Rear-Admiral Sir T. Williams, president, when Captain Wilkinson, in his statement to the court to account for the accident, mentioned the following particulars:—

> " In comparing the logs of his Majesty's ships Courageux and Reynard (then in company) there appears to have been a difference in the compass of from one and a half to two points easterly variation, as will clearly be determined by the comparison of the courses steered on the 13th of November, and which are certified by the log of the Reynard, confirmed by the signature of Captain St. Clair; and from subsequent comparisons and observations made on board H.M. ship under my command, with a variety of compasses, I am held out in stating that this has been the sole cause of the misfortune."
>
> " It is now for me," continued Captain Wilkinson, " to point out to the honourable court, that it had been usual prior to and after my

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* See copy of Regulations at the conclusion.

having command of this ship, that in order to be in constant readiness for immediate service, a stand of arms and various implements were placed immediately beneath the binnacle under the half-deck, and had hitherto not been discovered as holding any attraction to affect the compass; but on the various subsequent comparisons, which will be in evidence by the master and officers to have taken place, no other cause can possibly be ascribed to their error, because all the compasses brought from the Plantagenet and Reynard were found to correspond with those of the Courageux placed in the exact situation, either with the arms under the half-deck, or *vice versâ*, removed.

" It has been usual for the master and officers frequently to compare the compasses supplied the ship with each other, and if any were found defective to reject their use. I shall further request to observe that the Courageux was at the moment of grounding in charge of the pilot, who has been employed all his life in the Baltic, has a 'branch' for that sea, and in whose ability I put the greatest confidence. In adverting to this fact, I by no means intend lessening the responsibility attached to me as captain," &c.

Captain W., it appeared, was scarcely ten minutes altogether from the deck from eight to ten P.M. on the 13th of November. Men were placed to look out, and the lead was kept going as usual, and every precaution taken to prevent the unforeseen accident. But here let the evidence respecting the error of the compasses speak for itself.

Lieut. Charles Adam Lennock, in answer to questions from the court, stated he was present when a trial was made of several compasses after the Courageux's arrival at Wingoe:

" The removal of the arms from under the half-deck occasioned a difference of nearly two points.

" The Plantagenet's and Reynard's compasses were compared with those of the Courageux, and the arms had the same effect upon them, making an alteration of 1¾ point from what they were before they were placed in the binnacles.

" *Court.*—Were the arms removed from their place under the half-deck, and what was the effect of it?

" *Lieut. Lennock.*—The removal of the arms occasioned a difference of a point and three quarters."

Lieut. Roger Wollcombe, of the same ship, stated in his evidence that—

> "The arms were taken away from the half-deck a day or two before we arrived at Wingoe, and were replaced, which altered the compasses about one point and three quarters, making more easterly when under the influence of the arms. They were frequently tried by taking away the arms and replacing them, which made the same alteration, or nearly.
>
> "*Court.*—Is it your opinion, from the result of the experiments you witnessed for the purpose of discovering any error in the compasses, that the cause of the ship's running on shore on the night of the 13th of November last entirely arose from an error in those compasses?
>
> "*Lieut. W.*—It is my opinion."

Lieut. Charles Adam Lennock also stated that he was of opinion—

> "That the error in the compasses may be considered as the principal cause of the ship's getting on shore," and "believed the error in the compasses to have originated from no other cause than the arms being placed under the half-deck."
>
> "The Court, having maturely and deliberately considered every part of the inquiry and investigation into the particulars of the causes and circumstances attending the accident before mentioned, was of opinion that his Majesty's said ship, the Courageux, having struck on the said reef, was occasioned by an error in the compasses, in consequence of the marines' small-arms having been under the half-deck, immediately under the binnacle, the stand of which arms had been recently raised, which must have increased their power over the said compasses. The Court was further of opinion that there was no blame whatever attached to Captain Wilkinson, the master, and pilots: the Court did therefore acquit them."

The clear and conclusive evidence as to the cause of the serious accident to the Courageux so distinctly establishes the baneful effect of placing muskets or other arms near the compasses, that it does not appear to be necessary to quote in this place the more recent instances of disaster stated to have proceeded from a similar cause; more particularly as a stringent order, prohibiting such a practice in ships-of-war, has already been issued by the Lords Commissioners of the Admiralty.*

With respect to the equally serious consequences which may be apprehended from iron stanchions, bolts, or bars, being allowed to remain near the compasses in use, a few quotations from among the numerous authentic documents extant on the subject will, it is presumed, serve as a sufficient warning to all those concerned in this particular :—

Extract from the Remark-book of His Majesty's Ship Hastings.

"We sailed from Spithead on the 24th of April, 1838, having Lord Durham and suite on board, destined for Quebec. On the noon of the 25th we were in the latitude of the Lizard, and steered W.N.W. with the intention of taking a departure from the Lights. During the night, although a good look-out was observed, we saw nothing of our intended departure, and supposed we had been set to the southward. However, on our arrival in the St. Lawrence, we found that our binnacle compasses had been affected by the iron stanchions on the main-deck; in addition to a great quantity of iron placed in the capstan, fitted to work on our upper-deck, not being enabled to work the main-deck capstans on account of the cabins built for the accommodation of Lord Durham's suite.

"The local attraction of our compasses was found to be two points, so that instead of steering W.N.W., as we expected, we were actually steering west.

"It was during our run between Bird Island and Anticosti that we discovered the error of our compasses, owing to which the Hastings was very nearly run upon Cape Gaspé. The same evil occurred off Metis, in consequence of which the ship was placed in thirteen fathoms water, supposing, at the same time, we were in mid-channel."

The Remark-book, from which these extracts are taken, is signed by John C. Giles, Master H.M.S. Hastings.

The following communications from Captain Cator, R.N. and Sir John Franklin, so clearly demonstrate the evil of having small portions of iron-work near the compass, that their remarks cannot fail to convince every person of the necessity for great caution being observed in the construction or repair of ships, not to place any iron-work within the proscribed limits of the compasses:—*

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* See copy of the said order at the conclusion.

" *Brighton, February* 8, 1842.

" Dear Johnson,

" The case I represented to you verbally was as follows:—In the spring of 1811 I was ordered to take dispatches to Calcutta, in command of the Actæon sloop-of-war; and, being fitted for foreign service, I was supplied with an azimuth compass (H. M. vessels of that class not being then allowed one on the home station). I shaped my course with a leading wind from the N.N.W., to keep well out in the Atlantic, but I found my daily dead reckoning to be wide from the only chronometer I had; for while my course by log showed me to be far to the westward of Cape Finisterre, my chronometer showed me to be *scarcely weathering it.* To the best of my recollection I had no lunar observation, and it became a question whether my chronometer could have erred.

" To prove it, I assumed the chronometer was right, and, according to its longitude, I stood in to the eastward to make Cape Finisterre, which I soon made, and proved the chronometer to be right and the dead reckoning far wrong.

" A doubt arose then as to the compass pointing truly. I got the azimuth compass up, and found it was far in error. I moved the compass and found it pointed more truly.

" It was then ascertained that, while in dock, iron bolts had been put in the deck where the compass had stood on my voyage in command of the Actæon from the Isle of France.

" I represented by letter to the Admiralty or Navy Board (I forget which), that if I had not possessed a chronometer, or, by *not being fitted for foreign service,* and had no azimuth compass, we should (unless daylight had preserved us) evidently have run ashore on Cape Finisterre, when our dead reckoning showed us to be at least 100 miles to the westward.

" The Apollo and most of her convoy ran ashore in the early part of the war at or about where we were likely to have left our bones.

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* See Admiralty order.

All hands being lost, no one could tell the cause. But some ships of the convoy were saved by altering their course, seeing the evident error of the Apollo's course.

"In 1812, the Courageux, 74, Captain Wilkinson, was steering her course down the Belt with the Russian fleet (I was then also in command of the Actæon, escorting the Russian fleet from Cronstadt). She ran ashore and lost her rudder, and laid in Göttenberg (Wingoe Sound) all the winter.

"It was proved that her compasses were in error, owing to a stand of small-arms being placed under the binnacle *on the main-deck.*

"These are facts, and though long ago, fresh in my memory.

"Yours truly,

"B. C. CATOR, Captain R.N."

The Earl of Dundonald mentioned to me an instance wherein the Pallas frigate, which he then commanded on her way to Halifax, was thrown far out of her reckoning by a very similar cause to that described by Captain Cator; and the following letter from Captain Sir J. Franklin adds another occurrence bearing forcibly upon the same subject:—

"*H. M. S. Erebus, off Harwich, 20th May,* 1845.

"My dear Johnson,

"I am ashamed at having so long delayed writing respecting the compass errors of the Bedford, which I mentioned to you some time ago; but now that I feel myself relieved from the constant whirl attendant on the fitting out the expedition, I have much pleasure in doing so.

"In the winter of 1810, H. M. S. Bedford, after being docked and refitted, was ordered to the Downs, to join the fleet under the command of Sir Edward Pellew.

"We sailed from Spithead in the afternoon, and passed the Owers at a proper distance, taking the bearings of the Lights. The wind was fair, and the course was now shaped so as to pass the Dungeness Light also at a proper distance.

"Mine was the middle watch; and, not long after relieving the deck, I fancied we were closing in with the land more than was suspected by the master, and this became more evident to me when we saw the Dungeness Light.

"This opinion I made known to the captain and master; but the latter, knowing that he had directed the usual and proper course to the Downs, did not come up, and the captain directed me to be guided by the master. The course was accordingly continued until I perceived the ship to be getting in so fast to Dungeness, that I could distinctly see the point on which the light stands; and, finding the soundings decreasing, I could no longer hesitate in directing the course to be altered so as to get the ship off the land, and acquainted the captain of my having done so.

"The master then came on deck, and was extremely astonished at finding the ship close in with Dungeness Point. He, of course, attributed the circumstance to inattention and bad steerage; but I knew that the greatest care had been shown to the steerage since I had been on deck.

"On the following morning we anchored in the Downs. The most rigid inquiries were made by the captain as to the causes which brought the ship into her hazardous position, but without effect, until it was discovered, a few days afterwards, that a long iron bolt had been driven through the wooden stanchion of the companion hatchway, which was close to the binnacle; hence the cause of error became apparent.

"The iron bolt being removed, the compasses traversed properly, and gave correct magnetic bearings.

"If these facts can be of use to you, do with them what you like.

"We are getting on very well, towed at a good pace even against wind by the Rattler; the Monkey towing the transport.

"The wind, I think, is inclined to change.

"Believe me, my dear Johnson,
"Yours faithfully,
"John Franklin.

"*Capt. Johnson, R.N.*"

The occasional overlooking the old and sensible maxim to keep all kinds of iron seven feet distant from the binnacles, may have arisen, as before noticed, from the introduction of such large quantities of that metal into the art of shipbuilding, coupled, perhaps, with the erroneous view on that account which has already been alluded to; or it may have proceeded from the changes which are sometimes made in the position of the wheel after the ship has been constructed (particularly in steam-vessels), or from altering the plan and position of the binnacles, as in cases where holes have been cut in the deck to enable the compasses to be lowered and lighted from below, and thus occasionally bringing them close to the scarphs of the beams formerly bolted together with iron: but, from whatever cause any portion of that metal may have hitherto been suffered to remain near the compasses, it would be invidious to remark further than is necessary to impress caution; and therefore the quotations, from the abundant evidence on the subject, need not be multiplied in this place, more particularly as the readiness with which the officers of H.M. dockyards cause the evil to be remedied where-ever it is pointed out leaves no further cause for apprehension.

In many merchant-ships the necessary precaution of removing iron from the vicinity of the compasses is by no means sufficiently attended to, and in such vessels the evil is increased by their not being swung and the deviations ascertained; whereas in ships-of-war, by the system now adopted, should any portion of undiscovered iron remain within the influence of the compasses, the amount of error caused thereby is ascertained by the observations made during the process of swinging.

On inspecting a merchant steam-vessel which had been bought into her Majesty's service, finding the compasses were placed in one binnacle, so closely together that they could not fail to produce serious errors by their reciprocal action upon each other, I requested the binnacle might be cut in two and the compasses separated. In this operation it was found that the binnacle itself had been put together with iron nails and screws; three-quarters of a pound of the same having been extracted, and which are now in my possession; and in one instance the very box of the compass itself, which is placed inside the binnacle, had been repaired with iron nails!!

After the brig Livingston ran upon a sunken rock in 1826 and was nearly lost, on comparing the compasses, that by which she was steering at the time was found to be more than a point in error, owing to an iron strop which was found in the binnacle.*

Several remarkable cases bearing upon the subject may be found interspersed through the pages of the "Nautical Magazine;" and I may mention in this place that even those beautiful miniature specimens of naval architecture, the yachts, are not free from occasional difficulties, caused by iron bolts being driven too near their compasses, as I am informed their distinguished commodore, the Earl of Yarborough, can vouch.†

This division of the subject, however, has been sufficiently prolonged, and, perhaps, cannot be better concluded than with the following Table, containing the actual results of observations made on board her Majesty's steam-ship Styx when swung at Greenhithe.

1st. In 1842, when an iron crutch for the boom abaft was within magnetic range of the compass;

2d. In 1843, when the iron crutch was removed; and,

3d. In 1845, when the Styx was armed with a 42-pounder abaft and another forward, and two 42-pounders abeam.

The results contained in the Table are very marked, showing the effect produced by iron when differently situated with respect to the compass, by which it appears that under such circumstances both the points of *maximum* and of *no deviation* are changed, and likewise the amount of *deviation* itself.

The Styx having been navigated with perfect safety, according to the two first series of results, while under the command of Captain Vidal, during his arduous survey of the Azores, and afterwards, when armed, according to the third series, by Commander Hornby on the coast of Africa, affords an interesting specimen of the working of the compass system which has now been adopted.

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* To prevent improper materials from being placed in the binnacles, those of her Majesty's ships are now ordered to be made without doors.

† This passage was printed before the death of Lord Yarborough.

TABLE III.

Deviations of the Compass observed on board Her Majesty's Steam-ship Styx, under different circumstances.

Direction of Ship's Head by Standard Compass.	Iron Crutch abaft.	Iron Crutch removed.	Vessel armed.
	Deviation of Standard Compass, 1842.	Deviation of Standard Compass, 1843.	Deviation of Standard Compass, 1845.
North	6° 10′ E.	6° 8′ E.	2° 0′ E.
N. by E.	* 8 15 E.	7 27 E.	4 50 E.
N.N.E.	8 10 E.	8 18 E.	6 30 E.
N.E. by N.	7 50 E.	8 45 E.	9 15 E.
N.E.	6 10 E.	* 9 32 E.	9 30 E.
N.E. by E.	7 0 E.	8 37 E.	10 30 E.
E.N.E.	5 20 E.	7 15 E.	* 10 50 E.
E. by N.	4 10 E.	6 43 E.	10 0 E.
East	2 30 E.	4 4 E.	7 10 E.
E. by S.	o 0 10 E.	3 5 E.	6 0 E.
E.S.E.	1 0 W.	1 48 E.	4 30 E.
S.E. by E.	2 0 W.	0 23 E. o	3 0 E.
S.E.	2 50 W.	1 53 W.	1 31 E.
S.E. by S.	3 20 W.	2 50 W.	1 0 E. o
S.S.E.	5 55 W.	4 7 W.	1 40 W.
S. by E.	* 6 0 W.	5 48 W.	2 30 W.
South	5 40 W.	5 58 W.	3 20 W.
S. by W.	5 0 W.	6 18 W.	5 25 W.
S.S.W.	3 25 W.	6 40 W.	5 15 W.
S.W. by S.	1 50 W.	6 46 W.	6 30 W.
S.W.	2 15 W.	* 6 58 W.	6 40 W.
S.W. by W.	1 40 W.	6 25 W.	7 30 W.
W.S.W.	1 50 W.	5 41 W.	7 25 W.
W. by S.	0 10 W.	5 21 W.	8 7 W.
West	0 50 W.	4 56 W.	* 9 50 W.
W. by N.	o 0 10 W.	4 15 W.	9 0 W.
W.N.W.	1 15 E.	3 7 W.	8 30 W.
N.W. by W.	2 0 E.	0 58 W. o	7 0 W.
N.W.	2 55 E.	0 45 E.	6 25 W.
N.W. by N.	3 25 E.	2 17 E.	4 50 W.
N.N.W.	5 35 E.	3 37 E.	2 10 W.
N. by W.	6 40 E.	5 12 E.	1 0 W. o

The small discrepancies which occur are probably attributable to errors of observation.

* Points of greatest deviation. o Points of no deviation.

1850. Further experience has elicited many striking facts on this branch of the subject, a few of which, relative to the introduction of iron into the repair of ships, and their change of armament, it will be useful to record in this place; and likewise the marked differences which occur in the deviations of some steam-ships when their funnels are up and when they are down.

First, with reference to introducing iron into the repair of ships, in the vicinity of the compass, the following Table will serve to exhibit its effect in a conspicuous manner.

The difference of these results, it will be observed, are very remarkable, inasmuch as the deviations of 1848 show not only a large increase, but their usual directions in wooden steamers are reversed, the *least* deviation appearing when the ship's head was towards the *East* and *West*, and the *greatest*, or nearly so, when her head was towards the *North* and *South*.

This circumstance caused me much anxiety, for I could not in any way reasonably account for such a change. I therefore wrote to Commander Strange, and likewise to the master-shipwright where the vessel was last repaired, to inquire respecting the iron-work.

The result of these inquiries at once dispelled the mystery, and reconciled all the observations; for some of the Salamander's beams had been strengthened, during her last repair, with iron plates,* extending nearly from end to end, hence athwart the ship; and hence the deviations were *greatest*, or nearly so, when the ship's head was towards the *North* or *South*, and *least* when her head was towards the *East* and *West*.

Although, in this case, care had been taken at the dockyard to strengthen the beam nearest to the compass with copper instead of iron, yet the beam next to that was evidently a principal cause of the peculiarity in the deviations, and shows that 10½ feet is not a sufficient distance from the compass for iron plates of the nature described.

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* These iron plates were about 22 feet in length, 4¼ inches in depth, and three-quarters of an inch in thickness.

SUPPLEMENT TO TABLE III.

Deviations of H.M. Steam-sloop Salamander.

Direction of Ship's Head by Standard Compass.	Deviation of Standard Compass before the Ship's repair in 1842. Observer, Captain Johnson.	Deviation of Standard Compass after the Ship's repair in 1848. Observer, Commander Strange.
North.	0° 5′ W.	5° 0′ E.
N. by E.	1 0 E.	5 50 E.
N.N.E.	1 30 E.	6 40 E.
N.E. by N.	1 50 E.	6 0 E.
N.E.	1 55 E.	5 20 E.
N.E. by E.	1 50 E.	4 40 E.
E.N.E.	1 45 E.	4 10 E.
E. by N.	1 30 E.	2 30 E.
East.	1 20 E.	0 30 E.
E. by S.	1 5 E.	1 20 W.
E.S.E.	0 50 E.	3 0 W.
S.E. by E.	0 30 E.	5 0 W.
S.E.	0 10 E.	5 30 W.
S.E. by S.	0 5 E.	5 30 W.
S.S.E.	0 0	5 30 W.
S. by E.	0 10 W.	4 40 W.
South.	0 10 W.	3 40 W.
S. by W.	0 15 W.	2 20 W.
S.S.W.	0 20 W.	1 0 W.
S.W. by S.	0 20 W.	1 0 W.
S.W.	0 30 W.	0 20 W.
S.W. by W.	0 50 W.	0 10 W.
W.S.W.	1 40 W.	0 0
W. by S.	1 50 W.	0 0
West.	2 10 W.	0 10 W.
W. by N.	2 30 W.	0 10 W.
W.N.W.	2 30 W.	0 15 W.
N.W. by W.	2 0 W.	0 20 W.
N.W.	2 10 W.	0 10 E.
N.W. by N.	2 5 W.	0 30 E.
N.N.W.	1 30 W.	1 50 E.
N. by W.	0 50 W.	3 50 E.

Secondly, the following Tables, also supplementary to Table III., will serve to inculcate the necessity of re-swinging every ship when any material change shall have been made in the armament, or where repairs may have been effected in the vicinity of the compasses.

SUPPLEMENT TO TABLE III.

Direction of Ship's head by Standard Compass.	Cyclops.		Scourge.		Prometheus.	
	1845. Deviations of Standard Compass.	1848. Deviations of Standard Compass after the Ship had been repaired and her armament changed.	1846. Deviations of Standard Compass, a 13-inch mortar abaft.	1849. Deviations of Standard Compass, the armament being changed.	1844. Deviations of Standard Compass.	1850. Deviations of Standard Compass after the Ship had a thorough repair, new boilers, new funnel, &c.
North.	2° 30′ W.	1° 5′ W.	3° 0′ E.	2° 20′ E.	3° 7′ E.	0° 15′ E.
N. by E.	1 10 W.	1 30 E.	4 50 E.	3 10 E.	3 16 E.	2 10 E.
N.N.E.	0 20 E.	4 0 E.	5 40 E.	6 20 E.	4 22 E.	4 5 E.
N.E. by N.	1 30 E.	4 30 E.	6 40 E.	7 0 E.	4 55 E.	5 12 E.
N.E.	3 0 E.	7 55 E.	6 50 E.	6 50 E.	6 0 E.	6 20 E.
N.E. by E.	4 25 E.	8 50 E.	6 20 E.	7 40 E.	5 40 E.	7 0 E.
E.N.E.	5 10 E.	9 20 E.	6 50 E.	6 30 E.	5 35 E.	7 40 E.
E. by N.	5 30 E.	9 50 E.	5 40 E.	4 40 E.	4 30 E.	7 10 E.
East.	5 20 E.	9 45 E.	4 30 E.	4 0 E.	3 40 E.	6 40 E.
E. by S.	5 0 E.	9 0 E.	3 20 E.	2 20 E.	2 50 E.	5 25 E.
E.S.E.	5 10 E.	8 30 E.	1 50 E.	2 0 E.	1 27 E.	4 10 E.
S.E. by E.	4 40 E.	7 30 E.	0 40 E.	0 50 W.	0 30 E.	3 35 E.
S.E.	4 20 E.	6 40 E.	0 30 W.	....	0 10 W.	3 0 E.
S.E. by S.	3 30 E.	5 30 E.	1 40 W.	2 20 W.	1 42 W.	2 0 E.
S.S.E.	3 10 E.	4 50 E.	2 30 W.	2 30 W.	3 9 W.	1 0 E.
S. by E.	2 50 E.	3 10 E.	3 0 W.	2 20 W.	4 0 W.	0 20 W.
South.	2 15 E.	2 10 E.	3 30 W.	2 50 W.	4 45 W.	1 20 W.
S. by W.	1 40 E.	1 20 E.	4 10 W.	2 50 W.	5 28 W.	2 2 W.
S.S.W.	0 50 E.	0 10 W.	4 10 W.	2 40 W.	6 33 W.	2 45 W.
S.W. by S.	0 20 W.	2 0 W.	4 30 W.	4 20 W.	7 11 W.	3 42 W.
S.W.	2 0 W.	3 30 W.	4 30 W.	4 0 W.	7 42 W.	4 40 W.
S.W. by W.	2 50 W.	5 5 W.	5 20 W.	4 20 W.	7 51 W.	5 5 W.
W.S.W.	3 35 W.	6 30 W.	5 0 W.	5 40 W.	7 24 W.	5 30 W.
W. by S.	4 40 W.	8 5 W.	5 30 W.	6 10 W.	7 9 W.	5 50 W.
West.	6 10 W.	9 20 W.	5 40 W.	6 0 W.	7 30 W.	6 10 W.
W. by N.	7 0 W.	10 0 W.	4 20 W.	5 20 W.	6 49 W.	5 38 W.
W.N.W.	7 20 W.	10 35 W.	3 50 W.	5 10 W.	5 39 W.	6 30 W.
N.W. by W.	6 50 W.	10 25 W.	2 40 W.	4 30 W.	3 12 W.	5 15 W.
N.W.	6 40 W.	9 50 W.	1 40 W.	2 20 W.	1 20 W.	4 0 W.
N.W. by N.	6 20 W.	8 50 W.	0 40 W.	1 10 W.	0 32 W.	3 10 W.
N.N.W.	5 40 W.	6 40 W.	0 10 E.	0 0	0 32 E.	2 20 W.
N. by W.	4 0 W.	4 35 W.	1 30 E.	1 0 E.	2 26 E.	1 2 W.

Thirdly, the Table, p. 57, shows the marked differences which occur in the deviations of some steam-ships, when their funnels are up and when they are down.

When it happens that the funnels are at a great distance from the compass, as in the case of the Amphion (42 feet), and Hogue (66 feet), the differences are immaterial; but when they are near, as in the case of the Blenheim (22 feet), and Ajax (27 feet), and some others, the differences are so large that they cannot be safely neglected in practice. The broken lines thus —-- — in diagrams I. IV., &c. &c., upon the chart, show the large amount of error which would occur if the deviations were unknown, or not properly allowed for, under the two conditions of the funnel being *up* and *down*.

The Ajax when steering upon an easterly or westerly course with her funnel *up*, would, after a run of 24 hours only, be 50 miles out of her reckoning! and with her funnel *down* no less than 72 miles! while the case of the Blenheim would not be very different.

These facts are so striking that any comment upon their importance would be superfluous.

The Blenheim and Ajax having telescope funnels, it is evident that the difference of altitude of these, with respect to the compass, caused the difference of deviation, the greatest portion of the funnels when struck being then far below the level of the compass, and thereby adding to the influences of the other iron of the ship in that direction.*

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* I am indebted to Mr. Murray for the following particulars :—

Measurement of the funnels of the	Ajax.		Blenheim.	
	feet	in.	feet	in.
Height of the top of the funnel from the deck when *up*...	23	6	24	0
„ „ when *down*	4	6	8	0
Depth of the funnel below the deck when *down*	19	0	16	0
Diameter of the funnel (Ajax has two funnels abreast) each	4		6	0
Thickness of the iron	0	$\frac{3}{16}$	0	$\frac{3}{16}$
Entire depth of steam chest (below decks)	„		2	4
Thickness of the iron	„		0	$\frac{5}{16}$

When the funnels are down they consist of two parts, the external part and that adjoining the steam chest being considered *one*.

It would be interesting in a philosophical point of view to ascertain whether any or what portion of the differences were due to the induced magnetism of the inner portion of the funnel when down, acting upon the outer, or that part forming the base.

The case of the Sharpshooter was different, as the funnel worked upon a hinge, and when struck its head was 26 feet nearer to the compass than when elevated, being then nearly upon a level with the compass, and pointing towards it. The changes of the deviations in this case are very remarkable, and deserve especial attention.

The Ajax has two funnels placed in a line athwartships, 7½ feet apart from centre to centre.

It is proper to remark in this place, that in small vessels propelled by an *iron* screw, such as the Pioneer and Intrepid, when the screw is "out of gear," and secured on a level with the deck, its influence upon the binnacle compasses is very considerable.

TABLE

Showing the Differences in the Deviations of Her Majesty's Steam-ships Blenheim, of 56 *Guns (Engines* 450 *horse power); Ajax, of* 56 *Guns (Engines* 450 *horse power); and Sharpshooter Iron Steam-vessel, of* 4 *Guns (Engines* 202 *horse power), when their Funnels were up and when they were down.*

Blenheim, 56 Guns. 1847–8.			Ajax, 56 Guns. 1850.		Sharpshooter, 4 Guns, Iron Vessel. 1848.	
Direction of Ship's Head by Standard Compass.	Deviations of Standard Compass. Funnel *up*.	Deviations of Standard Compass. Funnel *down*.	Deviations of Standard Compass. Funnels *up*.	Deviations of Standard Compass. Funnels *down*	Deviations of Standard Compass. Funnel *up*.	Deviations of Standard Compass. Funnel *down*.
North.	1° 5′ E.	0° 20′ E.	0° 20′ E.	0° 10′ W.	0° 35′ E.	0° 0′
N. by E.	1 55 E.	4 0 E.	1 40 E.	3 20 E.	0 20 E.	2 20 E.
N.N.E.	2 25 E.	8 10 E.	6 40 E.	8 20 E.	0 10 E.	3 15 E.
N.E. by N.	4 20 E.	10 10 E.	9 10 E.	10 50 E.	0 0	6 50 E.
N.E.	6 45 E.	12 10 E.	11 20 E.	13 10 E.	0 30 W.	7 30 E.
N.E. by E.	8 10 E.	14 10 E.	13 20 E.	16 40 E.	1 40 W.	7 10 E.
E.N.E.	8 40 E.	16 10 E.	13 10 E.	18 30 E.	3 50 W.	6 0 E.
E. by N.	8 50 E.	16 10 E.	11 30 E.	16 30 E.	5 10 W.	5 10 E.
East.	9 0 E.	15 50 E.	11 50 E.	18 0 E.	7 20 W.	3 30 E.
E. by S.	8 30 E.	14 30 E.	11 30 E.	16 50 E.	9 10 W.	2 10 E.
E.S.E.	7 40 E.	13 20 E.	9 50 E.	15 0 E.	9 50 W.	0 20 E.
S.E. by E.	6 28 E.	11 40 E.	9 0 E.	13 10 E.	9 50 W.	1 30 W.
S.E.	5 5 E.	9 40 E.	7 30 E.	11 0 E.	10 40 W.	2 0 W.
S.E. by S.	3 40 E.	7 0 E.	6 10 E.	9 40 E.	7 50 W.	2 35 W.
S.S.E.	2 35 E.	5 30 E.	5 10 E.	7 10 E.	7 20 W.	1 30 W.
S. by E.	1 0 E.	2 30 E.	4 30 E.	5 50 E.	3 50 W.	0 40 W.
South.	0 0	1 30 E.	1 0 E.	2 10 E.	0 30 E.	0 50 E.
S. by W.	1 55 W.	0 50 W.	1 0 W.	0 10 W.	3 20 E.	1 40 E.
S.S.W.	3 15 W.	3 30 W.	4 0 W.	3 40 W.	5 50 E.	3 10 E.
S.W. by S.	4 43 W.	5 0 W.	4 0 W.	4 30 W.	9 10 E.	3 20 E.
S.W.	6 11 W.	7 0 W.	5 20 W.	8 40 W.	9 40 E.	3 20 E.
S.W. by W.	7 30 W.	9 0 W.	8 0 W.	11 50 W.	10 30 E.	1 45 E.
W.S.W.	9 40 W.	11 30 W.	10 50 W.	13 40 W.	9 0 E.	0 20 W.
W. by S.	11 10 W.	13 40 W.	13 20 W.	14 40 W.	8 10 E.	1 30 W.
West.	11 20 W.	15 40 W.	10 10 W.	16 40 W.	7 20 E.	4 40 W.
W. by N.	11 55 W.	16 30 W.	11 40 W.	14 30 W.	3 10 E.	5 20 W.
W.N.W.	12 45 W.	16 50 W.	11 40 W.	16 40 W.	2 50 E.	7 30 W.
N.W. by W.	12 5 W.	15 40 W.	10 0 W.	16 10 W.	1 0 E.	7 0 W.
N.W.	11 0 W.	13 40 W.	8 40 W.	14 30 W.	0 40 E.	8 40 W.
N.W. by N.	9 0 W.	11 20 W.	6 10 W.	11 0 W.	0 40 E.	8 20 W.
N.N.W.	6 35 W.	8 10 W.	4 40 W.	7 10 W.	0 40 E.	6 20 W.
N. by W.	3 5 W.	4 10 W.	2 50 W.	3 50 W.	0 40 E.	3 0 W.
Observers	Capt. Johnson and Commander Strange.		Mr. Thompson.		Comm. Strange.	
	Ft.	In.	Ft.	In.	Ft.	In.
Distance of Standard Compass from funnel	22	0	27	0	Funnel *up* 43 Funnel *down* 17	6 8
Height of Card from Deck	5	3½	5	8	4	0¼

III. *On the Errors caused by the reciprocal Action of Compasses upon each other, when (as is generally the case) the Binnacles are placed too closely together.*

The very obvious disturbance of any compass, when another is brought near to it, might be supposed to have acted as a salutary warning to those whose lives and properties are continually depending upon the correct working of these instruments, to keep them out of the reciprocal influence of each other when in use on board ship. This, however, is by no means the case, as the inspection of many hundreds of vessels at this moment in the river Thames will abundantly prove.

With respect to the ships-of-war the Admiralty have issued an order, that the binnacle compasses shall never be within the distance of 4½ feet from each other; and it would be highly advantageous were the commercial marine of the country to adopt a similar regulation.

In ships where the diameter of the wheel is small, one compass in front of it is by far the best plan, provided another compass be placed on some other part of the deck in the centre line of the ship, and be used for constant comparison and for immediate reference in case of accidents to that by which the helmsman might be steering.

The following Table of Errors, produced by the reciprocal action of compasses upon each other when placed two feet apart (which is a distance greater than that adopted in many of the vessels alluded to), will probably act as a more impressive caution than any words on the subject.

Be it observed, the results in this Table show the errors which are produced solely by the influence of two compasses (so placed) upon each other, and are entirely exclusive of the deviations caused by the ship's iron.

Table V.

Showing the Results of an Experiment made to determine the Errors which the reciprocal Action of Compasses, two feet apart, produce upon each other, when the Ship's Head is placed successively upon each point.

The correct magnetic bearing of the distant object was North.

Correct Magnetic Direction of Ship's Head.	Bearing of Distant Object by Port Compass.	Error of Port Compass.	Bearing of Distant Object by Starboard Compass.	Error of Starboard Compass.
N.	N. 0° 15′ W.	0° 15′	N. 0° 15′ W.	0° 15′
N. by E.	N. 4 30 E.	4 30	N. 4 40 E.	4 40
N.N.E.	N. 7 30 E.	7 30	N. 7 40 E.	7 40
N.E. by N.	N. 8 25 E.	8 25	N. 8 35 E.	8 35
N.E.	N. 8 5 E.	8 5	N. 8 20 E.	8 20
N.E. by E.	N. 6 45 E.	6 45	N. 7 0 E.	7 0
E.N.E.	N. 4 45 E.	4 45	N. 5 0 E.	5 0
E. by N.	N. 2 30 E.	2 30	N. 2 35 E.	2 35
E.	North.	0 0	North.	0 0
E. by S.	N. 2 30 W.	2 30	N. 2 30 W.	2 30
E.S.E.	N. 4 15 W.	4 15	N. 4 35 W.	4 35
S.E. by E.	N. 6 5 W.	6 5	N. 6 30 W.	6 30
S.E.	N. 7 30 W.	7 30	N. 8 0 W.	8 0
S.E. by S.	N. 8 5 W.	8 5	N. 8 30 W.	8 30
S.S.E.	N. 7 5 W.	7 5	N. 7 25 W.	7 25
S. by E.	N. 4 25 W.	4 25	N. 4 30 W.	4 30
S.	North.	0 0	N. 0 5 W.	0 5
S. by W.	N. 4 35 E.	4 35	N. 4 35 E.	4 35
S.S.W.	N. 7 20 E.	7 20	N. 7 30 E.	7 30
S.W. by S.	N. 8 35 E.	8 35	N. 8 40 E.	8 40
S.W.	N. 8 5 E.	8 5	N. 8 5 E.	8 5
S.W. by W.	N. 6 45 E.	6 45	N. 6 40 E.	6 40
W.S.W.	N. 4 55 E.	4 55	N. 4 50 E.	4 50
W. by S.	N. 2 45 E.	2 45	N. 2 40 E.	2 40
W.	N. 0 15 E.	0 15	N. 0 15 E.	0 15
W. by N.	N. 2 5 W.	2 5	N. 2 20 W.	2 20
W.N.W.	N. 4 15 W.	4 15	N. 4 30 W.	4 30
N.W. by W.	N. 6 15 W.	6 15	N. 6 20 W.	6 20
N.W.	N. 7 20 W.	7 20	N. 7 35 W.	7 35
N.W. by N.	N. 7 55 W.	7 55	N. 8 15 W.	8 15
N.N.W.	N. 7 10 W.	7 10	N. 7 30 W.	7 30
N. by W.	N. 4 35 W.	4 35	N. 4 40 W.	4 40

IV. *On the Imperfection of the Compasses.*

In consequence of very serious complaints having been made of the defective state of the compasses supplied to the navy, the Lords Commissioners of the Admiralty authorised Professor Barlow (in 1820) to examine the instruments in store, and report upon the subject.

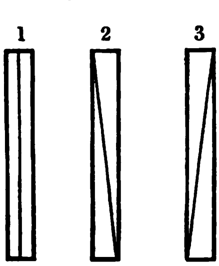
A copy of this Report is printed in the "Nautical Magazine" for 1837, by which it appears that these complaints were but too justly grounded; for Mr. Barlow, after having proceeded with the examination of the compasses at Woolwich, states, that—

> "He soon found it would be useless to examine the cards indiscriminately; for, out of the whole number, more than half of them would be considered as mere lumber, and which ought to be destroyed," &c. &c.

The causes of error, Mr. Barlow considered, might be reduced to the three following:—

> "1st. The errors which naturally appertain to the form of the needles usually employed in these instruments;
> 2d. To imperfect workmanship; and
> 3d. To the manner in which the compasses are kept in store."

With respect to the first of the above sources of error,* he remarks,—



"That the needles are commonly of a form approaching very nearly to a parallelogram, as shown in the annexed figures; and, consequently, the accuracy of the bearing of the card will depend upon the north and south points of the needle coinciding with the geometrical axis of the figure, as in figure 1. In this case, if the card be placed with its north and south points corresponding with the axis of the needle, it will be correct; but if in communicating the magnetic fluid to the needle the greatest accumulation should be oblique with respect to the axis, as in figures 2 and 3, then, the card being placed as before, its north point will bear to the east or west of the true magnetic north by a quantity equal to that obliquity."

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* This cause of error is very clearly pointed out by Mr. R. Walker, in his "Treatise on Magnetism," published in 1794.

This source of error may be avoided by suspending the needle edgewise.

"With respect to the imperfections in workmanship," observes Mr. Barlow, "it is needless to enter into detail. The cards are many of them elliptical rather than circular; true centering seems to be entirely disregarded, and what ought to be agate seems in many instances to be only common glass," &c. &c.

Notwithstanding this clear and most useful Report, complaints still continued to be made from time to time of the inefficiency of the compasses supplied to the navy; and circumstances having occurred, in which the badness of the compasses was represented as being the cause of some of her Majesty's ships running into danger, the Lords Commissioners of the Admiralty appointed a committee to investigate the whole subject, and which committee recommended many of the remedial measures which will be hereafter described.

1850. In addition to the causes of error in the old compasses, mentioned by Mr. Barlow in his Report, I may here notice another imperfection proceeding from a different source.

Having noticed, while experimenting in the Compass Observatory, that the magnetic collimator was disturbed when the bowls of some of the old azimuth compasses were approached towards it, I put them under a rigid examination, and on the application of the proper tests (hereafter described) I discovered that their brass bowls contained magnetic properties in themselves, some only in a small degree, but one of them to an extent not even admissible for the practical purposes of navigation, inasmuch as the compass bowl itself produced an error almost equal to that which would be caused by the iron of a ship of the line upon her standard compass when properly placed upon the poop.

The method pursued in testing the azimuth compass referred to was as follows:—

1st. The magnetic meridian at the moment was determined by means of the transit instrument and magnetic collimator.

2d. The azimuth compass bowl was placed upon the north pedestal with the "lubber-line" at north, and its pivot carefully adjusted in the line of collimation or magnetic meridian for the said time.

3d. The card with its needle was now placed upon the pivot, and the bearing of the magnetic meridian mark for the moment was read upon the card by means of the transit instrument, the card being afterwards vibrated, and a second reading taken to insure accuracy.

4th. The compass bowl was next moved in azimuth a point to the eastward, or in other words, the "lubber-line" was turned to N. by E. The pivot being brought again very exactly into the line of collimation, and the bearing of the meridian mark taken as before.

5th. The bowl was then moved in azimuth a point to the westward, that is, with the "lubber-line" at N. by W., and the preceding system of observations effected, and so on, when the "lubber-line" was brought successively to N.E. and N.W., East, and West, S.E. and S.W., South, S. by E., and S. by W., and the bearing of the meridian mark observed and duly recorded, reference being made continuously to the collimator for the changes in the direction of the magnetic meridian, and the pivot of the compass adjusted accordingly.

The following Tables contain the results:—

Table I.			Table II.		
Azimuth Compass with Brass Bowl.			The same Azimuth Compass Card placed in a Copper Bowl, with the same Pivot.		
Direction of Lubber Line.	Bearing of Meridian Mark.	Amount of Error.	Amount of Error.	Bearing of Meridian Mark.	Direction of Lubber Line.
North.	0° 20′ E.	0° 20′	0° 0′	0° 0′	North.
N. by E.	2 00 E.	2 0	0 5	0 5 E.	N. by E.
N. by W.	2 30 W.	2 30	0 0	0 0	N. by W.
N.E.	0 20 E.	0 20	0 2	0 2 E.	N.E.
N.W.	0 15 W.	0 15	0 0	0 0	N.W.
East.	0 10 E.	0 10	0 0	0 0	East.
West.	0 15 W.	0 15	0 0	0 0	West.
S.E.	0 10 W.	0 10	0 10 W.	0 10 W.	S.E.
S.W.	0 10 W.	0 10	0 0	0 0	S.W.
South.	0 0		0 0	0 0	
S. by E.	0 45 E.	0 45	0 2	0 2 E.	S. by E.
S. by W.	2 10 W.	2 10	0 5	0 5 W.	S. by W.

It is not only evident by these observations that this brass bowl possessed magnetic properties, but the part of it which contained the most of that influence (viz. in the vicinity of the "lubber-line") is clearly developed. An error of ten or fifteen minutes might be attributable to friction upon the point or cap, but no such error as 2½ degrees can in this instance be traced to any other cause than that assigned, viz. the impurity in the metal of the bowl.

Since the above experiment was tried, I placed another compass-card in the same bowl, the needle of which being longer approached nearer to the inner surface, and the result proved that an error of 5 degrees could be produced.

Having reported these circumstances officially to the Lords Commissioners of the Admiralty, their Lordships have directed that all new compass bowls which in future may be required for her Majesty's service, are to be made of pure copper, and that the mixed metal which may be necessary to form the axes, margins, verge, and azimuth vanes, shall be proved by the makers to be free from magnetic properties before it is applied to the compasses.

The brass frame-work of a dipping-needle having been approached towards the collimating magnet in the observatory, and a marked disturbance observed, I mentioned the circumstance to Admiral Sir F. Beaufort, who desired that the brass-work of several theodolites and small prismatic compasses might be tested. The result proved that many of them possessed magnetic properties, and some to an extent that would be likely to vitiate any observations for variation made with them.*

These facts, it is presumed, will be sufficient to convince the makers of the absolute necessity for the strict examination of the metal before it is applied to the instruments.

V. *On the Rough Usage, &c. of Ships' Compasses, and of the Erroneous Supposition that Correct Bearings may be obtained from any part of a Ship, without having ascertained the Deviations of the Compass in the particular place from which such Bearings have been observed.*

Considering that when an injury happens to the pivot, cap, or magnetic needle of a compass, it is at once rendered inefficient, surely it is not unreasonable to expect that on all occasions it should be conveyed to the ship, and be preserved with as much care as a chronometer; for, be it observed, the beautiful and useful application of the latter instrument for navigating the open ocean is of infinitely less importance than the correct working of the mariner's compass when threading the intricate channels of our own shoal-bound coasts.

To the rough usage, however, which compasses often receive, even at the hands of those who are to be guided by them, some of their errors may be attributed; and the practice of conveying them on board-ship like common stores, or, as has been observed, "like bags of nails, with which they were often doomed to keep company," cannot be too severely condemned.

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* Colonel Sabine mentioned to me a circumstance which occurred to Dr. Lloyd, wherein a series of dip observations had been rendered valueless by the discovery that the framework of the instrument was magnetic.

Of the erroneous supposition that correct bearings may be obtained from any part of a ship without having ascertained the deviations of the compass in the particular place from whence such bearings have been observed, perhaps the following bearings taken from different positions on board two steam-vessels at Greenhithe may be the best exposition, and at the same time serve as a useful warning on the subject:—

Bearings of a Distant Object taken from different positions on board Her Majesty's Steam-vessel Bulldog.

Correct magnetic bearing, N. 63° W.

Bearing from near the taffrail,
N. 60° W. Error 3°.

From abaft the paddle-box,
N. 73° W. Error 10°.

From the forecastle,
N. 59° W. Error 4°.

These errors would necessarily differ with every change in the direction of the ship's head; and should the place of the compass on board be altered only a few feet, the amount of deviation would likewise be changed.

Bearings of a Distant Object taken from different positions on board Her Majesty's Iron Steam-vessel Myrmidon.

Correct Magnetic bearing, N. 63° W.

Bearing from near the taffrail,
N. 70 W. Error 7°.

From abaft the paddle-box,
S. 66° W. Error 51°.

From the forecastle,
N. 82° W. Error 19°.

The object was so distant that there could be no parallax appreciable on the bearings taken with a compass at the extreme ends of the vessel.

Having now remarked upon the several sources of compass errors enumerated at the commencement, it will be essential to proceed with the explanation of the remedial measures which have been adopted with respect to the construction of the compasses for the navy, the method of testing and placing them on board ship, and of ascertaining and allowing for the deviations caused by the iron in the ship.

Some Account of the Measures adopted for improving the Compasses of the Royal Navy, the Plan of Testing them, and the System of Placing them on board Her Majesty's Ships, ascertaining the Deviations, &c. &c.

The Committee appointed by the Admiralty having examined a number of compasses sent for the purpose from the Naval Stores, and finding them very defective, proceeded to ascertain whether any great improvements had taken place in the construction of the mariner's compass in other countries. The result of their inquiries, however, showed that other nations were as much in arrear as our own in this respect; and I may here observe that the subject is surrounded with more difficulties than is generally imagined, for, although the construction of a correct magnetic instrument for purposes on land may not be impracticable, yet, where such accuracy is desired to be combined with the other qualities essential in a ship's compass, the question assumes quite another form, as will be subsequently shown.

After examining specifically into the different branches of the subject, the Committee commenced to devise means for correcting the errors complained of in these important instruments.

Professor Christie undertook to make experiments with different kinds of steel and its alloys, with a view of ascertaining that which had the property of receiving the greatest magnetic power, &c. &c.; and, after a most elaborate investigation (which it is to be hoped may be published in full) of the following kinds of steel, viz. clock spring, best cast steel, Market's patent steel, Vauxhall steel, Huntsman's cast steel, London Bridge steel, Woots or East India steel, steel alloyed with silver, with platinum, with rhodium, with iridium, and with palladium; he found that the clock spring was capable of receiving the greatest magnetic power, and that compound needles of this kind of steel had greater power or intensity than solid bars of the same dimensions and weight.

It was afterwards ascertained that the Strasbourg clock-spring (after it had undergone the process in Paris of making it into springs for chronometers) was capable of receiving an augmented magnetic power; and later experiments lead me to believe that, by a careful selection of steel in this country, and a proper process of hammering, hardening, and magnetising it, we shall obtain compass-needles of quite sufficient magnetic power.[*]

Since M. Arago's discovery of the influence which metals and many other substances exercise upon the magnetic needle,[†] Sir W. Snow Harris has ingeniously applied the principle to a compass by placing a thick copper ring in the compass-bowl, and allowing the poles of the needle to approach very near to it, by which the oscillations are very much reduced.

The Committee, on considering the difference of oscillations made by the same needle and cards placed upon the same pivot,—1st, in a copper ring, and 2d, in a copper bowl, $\frac{1}{10}$th of an inch in thickness,—preferred for practical purposes afloat the copper in its more expanded form of a bowl.[‡]

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[*] The Rev. Dr. Scoresby showed, some years ago, a method of making good compass-needles; and the Rev. T. Dury has since sent a number of excellent specimens, made according to a plan of his own; and I must not omit to mention that Mr. Walker has lately forwarded me some solid needles forged from the steel in Devonport Dockyard and hardened by his process, the magnetic power of which is ample.

[†] See "Annales de Chimie et de Physique," vol. xxvii. (1824.)

[‡] For the effect produced by copper upon the oscillations of a magnetic needle, see Sir W. S. Harris's paper in the "Philosophical Transactions, 1831;" and for a description of his compass, see a pamphlet printed by R. W. Stevens, Plymouth.

Several of Sir W. S. Harris's compasses are at present on trial on board her majesty's ships, and likewise those of Mr. Walker and Mr. Dent.*

On examination of the compass cards, sent for the purpose from the Naval Stores, Professor Barlow's description of them was found to be rigidly correct, "many being elliptical, and others being anything but circular," &c. &c.

After numerous experiments, the remedy for this evil was ascertained to be in first cementing the paper to the mica with a preparation not much affected by damp or heat, and then, by means of a powerful printing-press, obtaining the impression from the plate. By the use of a graduated azimuth circle, divided by an engine, and fitted so as to move round the margin of the bowl, without disturbing the pivot, a close approximation to a correct centering of the needles and cards is obtained, and likewise their adjustment to the magnetic meridian, which will be hereafter described.

The following brief description of a standard compass,† will sufficiently denote the principles on which it is constructed, and the annexed explanation of testing these instruments will show how any inaccuracy may be detected:—

The magnetic needles employed are compound bars or laminæ, of that kind of steel which has been ascertained by numerous experiments to be capable of receiving the greatest magnetic power; and the compass bowl is of copper, which is found to calm the vibrations of the needle to a considerable extent.

The intersecting point of the axes of the gimbals is made to coincide with the point of suspension of the card, and also with the centre of the azimuth circle; and the impressions of the cards being taken off after the paper has been cemented to the mica, distortions by shrinking are prevented, and a more perfect centering is attained.

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* For an explanation of the principles on which Mr. Walker's compass is constructed, see "Nautical Magazine;" and also a notice in the same work of the compass constructed by Mr. Dent.

† The first of these standard compasses were made by the late Mr. Robinson, and were afterwards improved by the late Mr. W. Gilbert, who applied to them his invention of the "direct prism." Since Mr. Gilbert's decease (with the exception of a few instruments by Mr. Stebbings and Mr. Cox), Mr. Henry Barrow, of Oxendon Street, has constructed the standard compasses, and to whom the credit of several suggestions for their further improvement is likewise due.

The points of the pivots are made of a material which is harder than steel, and which does not corrode by exposure to the atmosphere,* and the ruby caps are worked to a form to suit the points.

Spare points of hardened steel are likewise supplied: these are gilded by the electrical process.

The cards and needles are adjusted to the magnetic meridian in a place free from the local influence of iron.

The following instructions are issued with each standard compass:—

"This instrument is so constructed as to answer the purpose of a steering compass and an azimuth compass, and it being in charge of the captain or commanding officer, it is expected to be used with the care due to the nature of its construction, which has been briefly explained.

"I.—*When the Instrument is used as a Steering Compass.*

"Be very careful to preserve the *pivot-point* from injury when screwing the pivot into the bowl, and place the card gently upon it; and never move the compass without first having lifted the card (by means of the side screw) against the centre-pin. This should be done also before any guns are fired.

"The pivots, caps, and margins of the cards should be examined occasionally to see that their free working is not impeded by dust or fibres from the paper; and as each compass is furnished with two cards and six pivots, whenever the card works sluggishly, or injury by accident or long wear be suspected, the spare card or (as the case may be) a new cap or pivot should be put on. The central cap-screw, or nut on the face of the card, must be taken off before the ruby cap is attempted to be unscrewed.

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* See a paper by the author of this work, "On the Application of 'Native Alloy' for Compass Pivots," printed in the Report of the British Association for the Advancement of Science, 1840.

"When the card A is not sufficiently steady, the heavy card J, with the particular pivot appropriated to it, is to be used.

"When the bowl does not work freely on its gimbals, the axes and their bushes should be examined and slightly rubbed with plumbago.

"The bottom of the box is made to take out, so that the compass, when placed in the binnacle, or on the standard pillar, may be lighted from below, if necessary.

"The cover of the bowl is fastened by bayonet notches, and is to be removed before the azimuth circle (which has its own glass cover) is put on.

"The card should be adjusted for dip by the balancing slides when necessary.

"II.—*As an Azimuth Compass.*

"Any one of the compasses may be immediately converted to this purpose by lifting it upon its stand, removing the glass cover, and fixing the azimuth circle on its upper margin.

"In observing amplitudes and azimuths at sea, the bearings are read from the card, without reference to the external graduated circle.

"This instrument may also be used for surveying purposes. By adjusting the zero of the graduated circle to any given object, and clamping the instrument on its stand with the screw prepared for that purpose, the angles of objects round the horizon may then be observed, and read off to the nearest minute.

"Again. When accurate magnetic bearings on land are required, the zero of the circle may be adjusted to the magnetic north or south shown by the card, and then clamped; thus any number of magnetic bearings round the circle may be obtained."

COMPASS OBSERVATORY.

With the view of carrying out the proposed improvements in the construction of the compasses for the navy, the Board of Admiralty directed a wooden observatory for magnetic purposes to be erected near Woolwich, where these instruments, or others which may be proposed for the service, can be properly tested. A suitable position remote from other houses having been selected, terms were granted by Sir T. M. Wilson, Bart. to prevent the too near approach of future edifices.

At a proper distance from this, a building, containing offices for the reception of instruments, and for experiments, together with an officer's room and a dwelling for the person in charge of the observatory, has been erected. One room in this edifice is appropriated to the reception of specimen compasses of different nations and times, or which have anything peculiar in their construction; and this plan of preserving such specimens has already proved useful, in assisting to form a correct judgment of the merits of new propositions for the improvement of the compass. Another room contains a variety of apparatus for experiments with iron, steel, magnets, &c.; and another is appropriated to the galvanic apparatus and deflecting instrument, &c.

In the compass observatory are placed three pedestals, separated from the floor, the centre bearing a magnetic transit instrument, the south a magnetic collimator; and the north pedestal is constructed so as to receive any compass to be tested. Two shutters in the roof open upon the heavens in the direction of the *True Meridian*, which has been determined by observations on the stars, and a meridian mark put up accordingly; so that by this means, combined with that of the transit instrument and magnetic collimator, the *Variation* can be obtained at any time.

The transit is fitted both with an altitude and azimuth circle, and with the usual means of adjusting the axis, line of collimation, &c. &c. The magnetic needle employed is an edge-bar, which has the means of being reversed by the manner in which its cap is fitted.

With this transit* a very close approximation to the truth, as respects the magnetic meridian, may be obtained at any time, by observing both poles of the needle, first direct and then reversed, both in a wooden and in a copper bowl.

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* This transit was made by Mr. Jones, Charing Cross, and the magnetic collimator has been arranged to suit the position in which it is placed by Mr. W. Jones, who has had great experience in such subjects. The other apparatus for testing the compasses was made by Mr. Henry Barrow.

In order, however, to have a check upon this method, and to ascertain the magnetic meridian yet more correctly, recourse is had to the magnetic collimator on the south pedestal, the needle of which (having a proper lens and scale attached, and being suspended by a fibre of silk) enables the observer to obtain most minute results.

The method of ascertaining the magnetic meridian with this instrument is precisely similar to that which has been adopted in the magnetic observatories abroad by the artillery officers, under the able direction of Lieut.-Colonel Sabine, and which is clearly explained by Capt. Riddel in his " Magnetic Instructions."

The telescope of the transit instrument having been focally adjusted to infinite distance by an observation upon a star, and the magnetic meridian having been ascertained by the collimator, the field-glass of the transit is then directed to the north, and a corresponding mark to the line of collimation (or magnetic meridian) is observed upon a wall built for the purpose, about half a mile distant, with the same focal adjustment of the telescope.

The pivots, caps, lifter, gimbals, &c. &c. being duly scrutinised, and the metal of the instrument examined by the ordinary process, if free from permanent magnetism, the bowl of the compass to be tested is then placed upon the north pedestal, and by means of a movable plate, with antagonist screws, its pivot is brought into the line of collimation, corresponding with the mark upon the wall. The card, having been previously examined as to its balancing, &c., is now placed upon the pivot, and an observation is made with the telescope to ascertain whether the north and south points correspond with the said line of collimation.* The azimuth circle is next placed upon the bowl, and its sight vanes directed to the mark before-mentioned; and the direction of the card being "read off" by means of the prism, should the readings in this and the former case be zero (or north and south), then such card is considered to be in adjustment, so far as its magnetic axis is concerned; and the examination of the other adjustments is proceeded with, the results of which are entered in a register kept for the purpose.

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* 1850. It may be useful to notice, in this place, that the plan of using different lenses has been adopted, experience having taught that when a

The centering of the card is tested by turning the azimuth vanes successively to four or more parts of the external graduated circle, and comparing the readings with those on the card's graduation.

The magnetic power of the needles is ascertained by the amount of deflection they produce upon a standard needle at a given distance, similarly to the method which Dr. Scoresby showed to the committee, and which I think preferable to the plan of measuring the needle's power by the weight of iron it will suspend * (the standard needle being referred to the torsion instrument for its own power when necessary), and the tangent of the angle of deflection is taken as the measure of power. The bearing of a distant object or a mark upon the wall before-mentioned, is then observed with the lubber-line of the bowl successively at north, east, south, and west (by which process the pivot is likewise turned), and the needle being vibrated at each observation, the results are registered thus:—

Direction of L. Line.	Bearing of Object.	Ditto after Vibration.
	° ′	° ′
N	— —	— —
E	— —	— —
S	— —	— —
W	— —	— —

By this process, should there have been any undiscovered

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different focal adjustment of the telescope is required for a different distance, the usual kind of *rack-work* is not sufficiently accurate for our purpose. The position of the lens, when free from error, is determined in the usual way.

* Mr. James Brunton, who has charge of the observatory, has made himself extremely useful in the examination of these instruments, and likewise in other magnetic observations.

impurity remaining in the metal of the bowl, in all probability it would be made apparent, and any inaccuracies of practical importance in the centering of the pivot or the working of the card are certain to be discovered. Each standard compass, after being thus tested, is sent on board one of her majesty's ships, or steam-vessels, where it is placed in a position purposely selected, as far from iron as may be practicable or convenient. The ship is then swung, either at Greenhithe, where five buoys have been laid down for the purpose, or at Portsmouth, Plymouth, or Sheerness, as the case may be, and the deviations ascertained according to the system explained in the "Practical Rules,"* and an official report of the working of the said compass, after several months' trial at sea, is returned by the officer in whose charge it was placed; for, without the correct working of the compass afloat, the preliminary precautions would be of little avail.

Erroneous conclusions are sometimes drawn as respects the comparative merits of different compasses, inasmuch as the steadiest is not unfrequently considered the best, whereas it may happen that the reverse is the fact; as in the case of the old instruments, where the weakness of their needles' magnetism, blunt pivots, rough caps elevated considerably above the plane of the card, or the appliance of some additional friction, produced steadiness at the expense of accuracy.

It has already occurred, however, in small vessels propelled by the screw, and some others, that the compass suspended in the ordinary way is not sufficiently steady under their violent or peculiar motions; and hence it has been found essential to entertain the plan of a heavier card and some modification in the suspension to meet such exigencies. Compasses on the plans of Sir W. S. Harris, Mr. Walker, Mr. Dent, and Mr. Preston, are likewise under trial, to ascertain their properties under such circumstances.

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* These observations are made either under my immediate superintendence or that of my assistant, Commander J. N. Strange, R.N., in whose accuracy I have the most perfect confidence.

1850. Commander Strange having been appointed to the command of a ship, the Admiralty have ordered the masters of the flag-ships to be put in communication with me, and to superintend the swinging of H. M. ships at the out-ports.

It may be proper to mention, that the object which has been kept in view in the construction of the standard compasses has been to elevate the character of the compass from a rude machine to a correct instrument, because, without an approximation to accuracy, the amount of a ship's local attraction could neither be ascertained with precision nor be allowed for with confidence or certainty; and in order to attain to this, the somewhat expensive, but absolutely necessary appendage, the azimuth circle, is attached to each standard compass: so that the adjustment of the card to the magnetic meridian, and the general concentricity of the instrument, can be properly tested, as described at p. 70. And it may here be observed that, whatever improvements may hereafter take place in the compass cards, these circles will still be available.

A free and delicate suspension of the card is likewise necessary to obtain any results which can be relied upon; and hence that adopted in the lighter cards, which are used for ascertaining the deviations.

Strength and durability under the trials to which these instruments may be exposed at sea have been duly considered, in conjunction with a simplicity of construction, which admits of any imperfect working of the compass being readily discovered and easily and promptly rectified, as explained in the Instructions which accompany each instrument.

It is but justice to mention in this place, that the Committee had the advantage of receiving much information from Captains Sir E. Parry, Beechey, and Fitzroy, respecting the compasses they had employed on their several voyages of discovery, and many reports and suggestions from the late Capt. Hewett, and likewise from Capt. Becher, as to the working of the trial compasses afloat, before a plan of construction was decided upon; and since then, great advantage has been derived from the criticisms of officers on board vessels of different sizes, under various circumstances and in different regions, from Captains Washington, Stanley, Sir T. Pasley, Hammond, &c., besides many valuable communications from the masters of her majesty's ships at home and abroad. And I must here express my thanks to the commander of her majesty's steam-vessel Garland (Mr. Smithett) for the many trials he made of different kinds of compasses on board the Princess Alice, and for his most useful Reports; it being of great importance to obtain a steady compass in small vessels which have rapid and violent motions.

Having already alluded to the difficulty of combining accuracy with the other qualities necessary in a ship's compass, it may be useful to mention a fact which occurred at the commencement of this compass system, viz. that after a standard compass had undergone every ordeal as to accuracy on shore, from the delicacy of its suspension it was found to be too unsteady for use under the heavy rolling motions of a ship of the line; * and a similar unsteadiness was likewise observed on board some steam-vessels; and as the former imperfection of the standard compasses has been circulated in print, it may be proper to mention that, in order to remedy this defect, a heavier card, with augmented magnetic power in the needles and a slight modification in the manner of its suspension, has been supplied, and the reports of the working of these cards, which have as yet been received from officers on board ships in North and South America, the coast of Africa, West Indies, Mediterranean, and North Sea, are so far satisfactory. The official report of Capt. Kellett, C.B., after rounding Cape Horn in her majesty's ship Herald, states, that "the standard compass has proved steady under all circumstances;" and in another letter he mentions "that

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* Two more examples of this kind have also been reported.

the Admiralty compasses, both standard and common, are perfect, so far as their steadiness and directive power goes." And the almost singular degree of accuracy with which a ship's course may be directed, when attention is paid to the steerage and the proper allowance is made for deviation, is forcibly illustrated by the following severe test to which Capt. Stanley put the system by observations with the standard compass of the Blazer:—

> "During the course of last year, after shifting the Tender over forty-eight miles of ground by compass bearings, and distances obtained by the micrometer angles of her mast-head, we found, on again closing the land, that her position agreed within a mile of that given by angles to shore objects. So close an approximation I do think is a strong proof how well the compass must have worked, and how perfectly it had been corrected for local deviation."

It is intended that all the standard compasses should be of the same size, and that their cards, caps, pivots, screws, &c. &c. should be precisely similar. It is likewise proposed that all the *new* binnacle compasses (as soon as they can be made accurately and in sufficient numbers) should be of the same size as the standard, and that the upper margin of their bowls should be fitted to receive the azimuth circle; and thus not only give the means of testing their accuracy, but, in case of any accident happening to the standard, any one of them may be used for that purpose.*

TRIAL OF COMPASSES IN BOISTEROUS WEATHER AT SEA.

1850. As the unsteadiness of compasses of the ordinary construction, in boisterous weather at sea, particularly in small and fast steam-vessels and those propelled by the screw, causes much inconvenience, it may be mentioned here, that endeavours have been made to construct a compass that shall be sufficiently steady to steer by under any circumstances; and in order to test several compasses prepared by different individuals to effect this purpose, I proceeded to Ostend by direction of the Lords Commissioners of the Admiralty in the steam-packet Garland, then commanded by L. Smithett, Esq., and accompanied by Mr. Dent.

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* 1850. This proposition has been rescinded for the present.

On the outward passage the weather was too fine to be available for the objects contemplated, and all the compasses under trial worked well; but, fortunately, a strong gale from the N.W. sprung up during the night, and the next day afforded an excellent opportunity of testing the several compasses, so far as their comparative steadiness in rough weather was concerned: for it is scarcely possible to imagine any greater variety of motions than those which are produced in crossing the Flemish Banks obliquely in a gale, the alternate depth and shallowness of the water producing a kind of wrangling sea, which, combined with the speed of the vessel (14 knots), varied these motions in a remarkable manner,—from those of rolling, produced by a swell, to the sharp jerking and twisting movements occasioned by the breaking sea.

The compasses tried on this occasion were,—

1st. The standard compass on its elevated pillar.

2d. Mr. Dent's large compass in the binnacle.

3d. A liquid compass, on the late Mr. Preston's plan, placed on the quarter-deck.

4th. A compass in treble gimbals, much weighted at the bottom, and having the point of suspension elevated one-quarter of an inch above the plane of the card, the pivot passing through a brass collar, similarly to the plan in Mr. Walker's compass, and in the old compass by James Thompson.

5th. A binnacle compass with an edge-bar needle, ruby point, speculum metal cap, and four ivory pins, on the face of the card, upon my plan, the tops of these pins being one-eighth of an inch distant from the glass cover when the compass was level in its gimbals.*

6th. A compass by Messrs. Gray and Kean, of Liverpool, the card of which was suspended in double central gimbals, with two parallel needles working on axes so as to dip. The inner bowl was floated in liquid, and the outer bowl was suspended in the ordinary kind of gimbals.

The results of the trial may be briefly summed up as follows: — Mr. Dent's compass and Mr. Preston's liquid compass were the steadiest under all circumstances. Mr. Dent's compass having the advantage of being more sensitive in indicating any change in the direction of the ship's head.

The compass in treble gimbals upon the point of suspension passing through the brass collar, as in Mr. Walker's plan, and also compass 5th with the ivory pins on the card, on my plan, were sufficiently steady to steer by, until the sea, in its peculiar turbulence on these banks, struck the vessel from stem to stern, almost at the same moment when the cards of these compasses were observed to vibrate from one to one-and-a-half points, while that of the standard on one occasion vibrated twelve points; the card of the Liverpool compass swung half round, and that of the ordinary kind of compass spun wholly round.*

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* I have since added four glass beads, suspended by a silk cord so as to come within one-eighth of an inch of the face of the card when level. Neither the ivory pins nor beads, be it observed, impede the free working of the card, except under such violent motions of the vessel as the gimbals do not compensate for, and then they have a tendency to steady it; — the beads first gently preventing the card from taking a rotary movement; and should the motion of the vessel be yet more violent, as in the case of small and fast steamers in a gale, and where the bowl sometimes nearly topples over, then the ivory pins, in touching the glass cover, act as preventives to vibration, till the bowl and card recover their balance, and the latter is again perfectly free. These contrivances also prevent the card from being thrown off its pivot. A very favourable report of the working of these beads has been received from Mr. Welch, of H. M. yacht Fairy, where the motion is sometimes excessive; and by persevering in the trials, and adopting further suggestions for improvements, we may hope to obtain another description of storm-compass, or an instrument available under all circumstances in such vessels as the Fairy.

It may be worthy of remark, that on locking the gimbals of the standard compass (and the fact is curious) the vibrations of the card under this excessive motion of the vessel were reduced to two points,—a circumstance previously observed by Mr. Smithett on board the Princess Alice.

Mr. Smithett having noticed in his Reports, that when the vessel was running before the sea, or with the sea on the quarter, Mr. Dent's compass became unsteady, that circumstance has since occupied Mr. Dent's attention, and he has at present under trial some appliances to correct the defect.

In remarking upon the endeavours which have been made to produce a steady compass at sea under *extraordinary* circumstances, that is, under violent motions of the ship, it would seem that the question resolves itself into one of additional friction, and the best mode of applying that to steady the card under such circumstances, without impairing the accuracy of the instrument. This, however, is by no means an easy matter to accomplish; for the introduction of additional friction, if not most carefully adjusted with reference to the magnetic power of the compass needle, is certain to produce a sluggish compass when the ship is in smooth water. Hence it has been found advisable to have one compass, at least, in each ship of a construction capable of working well in a storm at sea, or under *extraordinary* circumstances; so that the more accurate compasses for general and ordinary purposes may not be altered or interfered with.

The compasses at present used for this purpose are,—

Mr. Dent's, Mr. Preston's, Mr. Walker's, and the compass on my plan.

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* A compass on Sir W. Snow Harris's plan has since been tried, and although it proved to be a good compass in ordinary circumstances, yet, under the excessive motions of these small vessels in a gale, it was likewise unsteady.

TRIAL OF COMPASSES ON BOARD SHIP WHEN THE GUNS ARE FIRED.

It is of considerable importance to have at least one compass on board each ship of war so constructed as to be sufficiently steady to steer by when the ship is in action, or broadsides are fired; and this is more particularly essential when a running fight takes place among shoals. And I may notice, in this place, the plan of the late Admiral Sir E. Owen, who had considerable practice in such matters: Sir Edward's plan to prevent the vibration of the card was to suspend the compass bowl by springs attached to the corners of the box; and this was found to answer well, provided the needle and card were suspended in the ordinary way, with a simple pivot and cap: but if they should be suspended in double central gimbals, such as are now frequently used, the vibration or disturbance becomes largely augmented.

The following experiments have been tried on board H. M. S. Excellent, with compasses of different constructions, with the view of ascertaining which plan counteracts the vibration occasioned by the firing of a ship's guns most effectually. The officers present during the trial were Captain Chads, Commander Strange, and myself, with Mr. Dent and several officers of the ship.

The following were the compasses tried:—

No. 1. Mr. Dent's compass.
No. 2. Mr. Walker's compass.
No. 3. Mr. Preston's liquid compass.
No. 4. The ordinary kind of binnacle compass.
No. 5. Large-sized binnacle compass, by Mr. Stebbing.

These compasses were placed successively in a given position, about seven feet from the breech of a 32-pounder, which was fired, first, with ten pounds of powder and without shot, and afterwards with the same charge of powder with shot.

The results were as follow :—

No. 1. Mr. Dent's compass. In no case did this compass vibrate more than ¼ of a point, and on these occasions the box itself was moved by the concussion.

No. 2. Mr. Walker's compass. In no case did this compass vibrate more than ¾ of a point.

No. 3. Mr. Preston's compass. Although the liquid in this compass was disturbed, in no instance did the card vibrate more than ¾ of a point.

No. 4. The ordinary binnacle compass: vibrated 4¼ points.

No. 5. Mr. Stebbing's large-sized compass : vibrated, on one occasion, 7 points.

With reference to boat compasses, many experiments have been made from time to time, during the last few years, to effect their steadiness when the boat is under sail or rowed with oars ; and of the boat compasses which have been tried by me, those which stood the prescribed tests the best were Mr. Dent's, Mr. Preston's, and Mr. Walker's : the ordinary kind of boat compass, under the same trials, being so unsteady as to be useless.

COMPASS-ROOMS.

For the better preservation of the instruments, a compass-room has been fitted up at each of the royal dockyards upon a given plan. Shelves are placed at a distance from each other in the line of the magnetic meridian, upon which the compass-cards are ranged two feet apart, with their north poles to the north; and should it be ascertained that the needles thus carefully placed with poles of opposite names nearest to each other lose much of their intensity, the remedy, it is considered, should be sought, not in re-magnetising such needles, but by rejecting them altogether, and procuring those made of better steel and more carefully hammered, hardened, and magnetised.

DEFLECTING APPARATUS.

A deflecting apparatus being kept at every dockyard, it is intended that the magnetic power of each compass-needle shall be ascertained and registered in a book kept for the purpose, before it is issued to any of her majesty's ships.

COMPASS-CLOSETS.

In every ship a closet has been directed to be fitted in a dry place, sufficiently large for the reception of the ship's establishment of compasses, and is to be appropriated to that purpose *exclusively*, the key being kept by the master; and in order that the compass-cards may never be kept with poles of the same name nearest to each other, cases, which prevent the possibility of their being packed improperly, are prepared.*

BINNACLES.

As the new compasses are gradually introduced, it is proposed that all the binnacles should be of the same pattern and size; and, to prevent improper materials from being placed therein, they have been directed to be made without doors.

BOAT COMPASSES.

The ordinary kind of boat compasses having been found of little use under the various motions of a boat, the discontinuance of their supply will be recommended as soon as the trials with several new kinds shall have been completed, and which already have proved very superior in their action afloat to the old boat compasses. Those upon the plans of Mr. Walker, Mr. Dent, and Mr. Preston, are at present under trial. The late Rear-Admiral Shirreff favoured me with many experiments and communications on this subject.

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* This is effected by attaching a small piece of wood to the side of each card-box, so as only to fit into its corresponding notch in the large case supplied; and whenever any card may be found defective, arising from accident or long use, it should always be returned to its proper place in the case. Much injury to the compass-bowls, &c., would also be avoided, if, under similar circumstances, they were likewise returned to their appropriate places in the compass-closet.

PLACING COMPASSES ON BOARD HER MAJESTY'S SHIPS.

The following copy of a Memorandum issued by order of the Board of Admiralty, respecting placing the compasses on board her majesty's ships, removal of iron from their vicinity, &c. &c., will supply any omission in the preceding details; and the accompanying copy of the "Practical Rules" for ascertaining the deviations, will complete the description of the measures which have been adopted with the view of remedying the evils complained of in the compass system generally:—

"*Admiralty, November* 20, 1845.

"MEMORANDUM.

"With reference to the several orders which from time to time have been issued respecting the removal of iron from the vicinity of the compasses, placing the binnacles and standard compasses on board her majesty's ships, &c.; and with the view of comprising these orders in one circular for the guidance of the officers concerned, my Lords Commissioners of the Admiralty are pleased to direct—

"That no iron of any kind shall be placed nor be suffered to remain within the distance of seven feet of the binnacle or standard compasses, when it is practicable according to the size and construction of the vessel to remove it; and that mixed metal, or copper, be substituted for iron in the bolts, keys, and dowels, in the scarphs of beams, coamings, and head-ledges, and also the hoops of the gaffs and booms, and belaying pins, which come within the distance of seven feet of the said compasses.

"The spindles and knees of the steering-wheels which come within the distance of seven feet of the compasses are also to be of mixed metal.

"Iron tillars, which work forward from the rudder-head, are not to range within seven feet of the compasses; and in vessels which have iron tillars working abaft the rudder-head, the binnacles are to be placed as far forward from the wheel as may be convenient for the helmsman to steer by.

"The boat's iron davits are to be placed as far as may be practicable and convenient from the compasses.

"All vertical iron stanchions, such as those for the support of the deck, or for the awnings, &c., and likewise the armstands, are to be kept beyond the distance of fourteen feet from the compasses in use, so far as the size of the vessel will admit.

"All steam-vessels are to be fitted with hollow pillars for the support of their standard compasses, except in such cases as the Superintendent of the Compass Department shall point out, in which instances a solid wood pillar, or mixed metal stanchions for the support of a copper binnacle-head, is to be prepared; and these pillars, or supports, are to be so placed that the said binnacle-head will be in the midship line, and in such a position forward, or aft, as the Superintendent upon consultation with the Master-shipwright shall think most advisable, according to the construction of the vessel and nature of her armament.

"In ships of the line and frigates, it having been found more convenient to place the standard compass in a copper binnacle, supported by mixed metal stanchions or a solid wood pillar, these are to be prepared according to the application of the Superintendent of the Compass Department.

"In brigs or other vessels, where the main-boom may prevent a standard or azimuth compass from being constantly kept at the proper elevation for observations, a solid pillar, made so as to unship, or a sliding tube, constructed so as to be capable of being lowered upon a short pillar, is to be prepared; whichever plan may be considered most suitable to the vessel, according to her equipment and armament.

"The binnacles for the steering compasses are to be constructed upon a given plan, with tops made to take off; and, in order to prevent improper materials from being deposited therein, they are not to be fitted with doors.

"As the vicinity of the compasses, when the binnacles are too close together, has been found materially to affect their accuracy, in all ships where there are two binnacles, they are to be separated as much as the diameter of the wheel will permit, and so as the helmsman may see the compass conveniently; but in no case are they to be allowed to be nearer than four feet six inches.

"For the better preservation of the compasses, in every ship a closet is to be constructed in a dry place, sufficiently large for the reception of the ship's establishment of compasses; and it is to be appropriated to that purpose exclusively, the key being kept by the Master; and in order that the spare compass-cards may never be kept with poles of the same name nearest to each other, cases, which prevent the possibility of their being packed improperly (specimens of which have been sent to each yard), are to be prepared.

"These regulations are to be alike applicable to ships ordered to be built, and to those directed to be prepared for commission; and the previous orders on this subject are to be considered cancelled.

"By command of their Lordships,

"H. CORRY."

The proofs which have been already adduced respecting the impurity of the ordinary brass of commerce for magnetic instruments may serve also as a caution against the yellow shining livery placed upon stanchions in the vicinity of the compasses, and beneath which the treacherous iron is too often found to lurk in the mischievous form of rods or bars.

1850. The following is the Establishment of Compasses for H.M. ships, ordered by the Lords Commissioners of the Admiralty:—

First, Second, Third, and Fourth Rates	1 Standard Compass. 1 Azimuth do. 5 Binnacle Compasses. 4 Boat's do. 1 Hanging Compass, or 2 in Flag Ships.	Fifth and Sixth Rates, and Steamers of those Classes	1 Standard Compass. 1 Azimuth do. 5 Binnacle Compasses. 3 Boat's do. 1 Hanging Compass.
All other Steam Vessels and Troop Ships	1 Standard Compass. 1 Azimuth do. 5 Binnacle Compasses. 2 Boat's do. 1 Hanging Compass.	All Corvettes, Brigs, and smaller Sailing Vessels	1 Azimuth Compass. 5 Binnacle Compasses. 2 Boat's do. 1 Hanging Compass.

One of the Binnacle Compasses in each ship is to be either on Dent's, Preston's, or Walker's principle.

PRACTICAL RULES

For Ascertaining those Deviations of the Compass which are caused by the Iron in the Ship, and which have been published by order of the Lords Commissioners of the Admiralty.

Standard Compass.

1. In every ship a good compass should be selected and called the Standard Compass, with which the binnacle compasses ought to be frequently compared, and by which all bearings ought to be taken. It should be placed on the midship line of the quarter-deck or poop, but as far as it conveniently can be from any considerable mass of iron, such as the spindle of the capstan or the stanchions; and in steam-vessels, from the chain peak haulyards, or the iron quarter-davits. It should be fixed on a permanent support or pillar, and at such a height above the deck as will permit amplitudes and bearings to be observed with it above the hammock-boards. This pillar might be hollow, so as to admit, in some vessels, of the compass being lighted from below. No stands of arms, or other iron, subject to occasional removal, should be placed within at least fourteen feet of this standard compass.

To stand on a pillar.

First process, by a distant object.

2. When the ship is ready for sea, with all her guns, shot, shells, armstands, and other iron stores on board, and in their proper places, her quarter-boats hoisted up to the davits, and the stanchions and all other iron-work secured in the positions in which it is intended they shall remain at sea,—then the deviation of the standard compass from the real magnetic meridian is to be ascertained in the following manner,—and if the ship be in a basin it can be executed at any time, but if riding in a tide-way at slack water only. The

First process, by a distant object.

requisite warps being prepared, the ship must be gradually swung round, with her head successively upon each of the thirty-two points of the compass; and, as her head comes to each of those points, her motion is to be gently checked, so as to prevent any swing of the card. When quite steady, and her head exactly on the required point, the bearing of some distant but well-defined object is to be observed with the standard compass, and registered according to the subjoined form, in Table I. The object selected for this purpose should be at such a distance that the space through which the ship revolves shall make no sensible difference in its bearing: if the ship be in a basin, six miles will probably be sufficient; but if at anchor in a tide-way, not less than from eight to ten miles' distance, or more, according to her scope of cable, will answer that purpose,—and the more distant the better.

Table I.

Real magnetic bearing.

3. The next step is to determine the *real* magnetic bearing of the object from the ship; or, in other words, the bearing which would have been shown on board by that compass if it had not been disturbed by the local attraction of the ship. This is to be effected by taking the standard compass to some place on shore, from whence the ship (that is to say, the part of the ship where the compass stood) and the object, of which the bearings had been observed, shall be in one with the observer's eye, or else in the exactly opposite direction.* The bearing of the object from that spot will evidently be its *real* magnetic bearing from the ship by the standard compass. The differences between this real magnetic bearing of the object, and the successive bearings which

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* If, from the position of the ship, with respect to the shore, this should not be practicable, the distance from the ship to the station of the compass ashore must be measured, and the horizontal angles, between each end of this base and the distant object, must be observed with a sextant, by which means the correct magnetic bearing that the object would have had from the ship may be readily computed. In many cases it may be more convenient to determine the real magnetic bearing of the distant object previous to the operation of swinging the vessel.

were observed with the standard compass on board, when the ship's head was on each of the several points, will show the error at each of those points which was caused by the ship's iron,—or, in other words, the *deviations* of the standard compass, according to the direction in which the ship's head was placed. These several deviations or errors, when her head was at each point, are to be registered in the manner shown in column 3 of Table I.

First process, by a distant object.

Table I.

4. The deviation, thus found, is to be called *east* when the north end of the needle is drawn to the eastward, or to the right hand, by the ship's attraction, and *west* when it is drawn to the westward, or to the left hand; this employment of the terms *east* and *west deviation* being precisely analogous to that of *east* and *west variation,* as understood by every seaman. And therefore, in applying the correction for the deviation to any course or bearing, he is to adopt the same method exactly as in the case of applying the variation: that is to say, he is to suppose his eye in the centre of the card, from whence, looking along the point in question, he is to apply the east deviation to the right hand, and the west deviation to the left hand.

Deviation, like variation, called east or west.

Examples.—I. If the ship's head by the standard compass be E.N.E., and the deviation (by Table I.) be 5° 22′ E., then the real magnetic direction of her head will be 5° 22′ to the right hand of E.N.E., or about E.N.E. ½ E.

Examples.

II. If, with the ship's head on the same point as in the above example, the bearings of two islands be S.E. and W. by S. by the standard compass, then, by applying the same correction, 5° 22′ E., and in the same way, the real magnetic bearings of those two islands will be S.E. ½ S. and W. ½ S.

III. Supposing it be required to make a correct S.W. course by the standard compass. The deviation found in Table I. with the ship's head S.W. is 3° 8′ west, or about the third of a point. This must obviously be applied *con-*

versely; and the ship must be steered S.W.$\frac{1}{3}$W.; because this course, when corrected by applying the 3° 8′ to the left hand, will give the real or correct magnetic course, S.W.

Second process, by reciprocal bearings of two compasses.

5. If there should be no suitable object visible from the ship, sufficiently distant for the purpose, the deviations must be ascertained by another process. A careful observer must go on shore with a second compass, and place its tripod in some open place, having no buildings near, so as to be free from the influence of any iron, and from whence it may be distinctly seen from the standard compass on board. Then, by means of preconcerted signals, the bearing of each of these two compasses from the other is to be observed at the moment that the ship's head is quite steady on each of the thirty-two points successively, as above directed. The mode of registering the observations, when this process with the two compasses has been adopted, is shown in Table II.

Table II.

6. The compass on shore should be as distant from the ship as is consistent with the most distinct visibility of both compasses from each other. The observations should be made as strictly simultaneously as possible; and to guard against any mistake, which might be occasioned by a signal being misinterpreted, the time at which each bearing is taken should be noted, both on shore and on board, by compared watches. The standard compass should then be carried on shore, in order to be compared with the compass which had been employed there, by means of the bearing of some distant object, and the difference, if any, is to be recorded. This comparison of the two compasses may be made previously to the observations; and in all cases when compasses are compared, the caps, pivots, &c. should be first carefully examined.

It has been found a very convenient practice for the observer on shore to chalk each observation upon a black board, so that it may be read by the observer on board the ship. By these means the deviation may be at once deduced;

and should there be any inconsistency in the results, the observations can be immediately repeated, and the necessity for again swinging the ship thus prevented.

Second process, by reciprocal bearings.

7. From the observations thus made, by either of the processes which have been described, a table of results is to be constructed for the use of the ship, as shown in Table III.; and it should be copied for his own use by every person on board who keeps a reckoning. By the first and third columns of this table, the courses shown by the standard compass are convertible, by inspection, into correct magnetic courses; and conversely, the course which should be steered by the standard compass, in order to make good any given magnetic course, can also be taken out by inspection. The second column shows the correction to be applied to all bearings taken by the standard compass, according to the direction of the ship's head *at the time* that *each* bearing was taken; and this correction is always to be applied precisely in the same manner as if it were variation of the same name.

Table III.

8. Table III., whether formed from Table I. or II., shows also the position in which the ship's head must be placed, in order that the ship's iron may produce no disturbance or deviation in the direction of the needle of the standard compass. This position will, in many ships, be on the north and south points, or nearly so; but in some ships, especially in steam-vessels, it will be found to differ materially from those points, so that it would be unsafe to depend upon anything but observation in this matter. Experience, however, has shown that when the points of no deviation in any vessel have been once determined in a compass, placed as above directed, and *always used in the same place*, they may be regarded as constant, provided that no extraordinary or unusual change be made in the amount or distribution of the iron in the ship. With this proviso, therefore, an azimuth observed at sea, with the ship's head on either of the points of no deviation, will give the correct magnetic variation.

Points of no deviation generally remain constant.

Azimuths and amplitudes should be observed with the ship's head on one of the points of no deviation.

9. To determine the true geographic courses, or bearings, from those shown by the standard compass, we have consequently two corrections to apply; one for the deviation, and one for the variation. The correction for the deviation is furnished by the second column of Table III., as above explained; and the variation may be obtained by an azimuth or amplitude, observed with the ship's head on one of the points of no deviation. If no azimuth or amplitude has been observed, recourse must be had to the variation charts and tables; but when circumstances permit, it is always most desirable, and cannot be too strongly recommended, to determine the variation by actual observation of the sun's azimuth or amplitude, taken while on the course which the ship is actually steering, and by the same compass, *i. e.* the standard compass. By these means, the two corrections, viz. for deviation and variation, will be obtained by one observation, and with no greater uncertainty than belongs to the observation itself.

The deviation varies in different regions of the globe;

10. Experience has shown that the amount of deviation on the several points varies in places distant from each other in latitude; and that in the southern hemisphere it generally becomes westerly on the points on which it was easterly in the northern hemisphere, and easterly where it was westerly. It will be indispensable, therefore, when a ship changes her geographic position *considerably*, and especially when she has passed from one hemisphere into the other, that an early opportunity should be taken of forming new tables by again swinging the ship, and repeating one of the above-mentioned processes.

and when near volcanic countries.

It may be here noticed, that it is not safe to rely on any results obtained when near the shore in volcanic countries; such as St. Helena, for example. In such situations it is better to determine the errors of the compass when the ship is outside the harbour and *under way*, by observing the bearing of some *very* distant object on the land, with the ship's head placed successively and steadily on the several points.

The deviation should be frequently examined at sea.

11. The deviation on the different points may be at any time examined at sea, and its correspondence, or otherwise, with the table, may be ascertained by observing azimuths with the ship's head successively on different points, one of which should invariably be one of the points of no disturbance. If the deviations thus found should agree with the tabular deviations, the table may be continued in use with additional confidence; but if they differ *considerably*, the new results must be further verified by the repetition of similar observations; and, if confirmed, the table should be re-formed as quickly as circumstances will permit. In a cursory examination, the points most important to compare with those of no deviation are the points of greatest deviation, which are usually 90° from them; and then the intermediate points of 45°.*

Iron vessels.

12. In iron vessels, it is desirable that the standard compass should be raised above the deck much higher than is necessary or convenient in sailing-vessels; but in all other respects the processes and rules above stated will apply to iron as well as to timber-built vessels.

Telescopic funnels.

In steam-vessels fitted with what are called telescopic funnels, the deviation is materially altered by the position of the funnel. For instance, with her head E., her Majesty's ship Blenheim has 9° deviation when the funnel is *up*, and 15°¾ when *down*. In swinging those vessels, therefore, it is absolutely necessary that on the eight principal points of the compass the deviation should be ascertained in both conditions of the funnel.

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* It is the more necessary to insist upon the necessity for making these observations continually, because it is possible that in some ships the magnetism of a portion of the iron may be *permanent*, while that of the remainder is *induced;* and it is obvious that the change of deviation, when passing from one magnetic hemisphere to the other, would not follow the same law in both portions.

Standard compass should be immovable.

13. Finally: the mariner must remember that the corrections found for the standard compass belong to that compass alone, and to that compass only while it is in its proper place; and that those corrections will furnish no guide whatever to the effects of the ship's iron on a compass placed in any other part of the ship. It is essential, therefore, that the ship's course should *invariably* be directed by the standard compass; and that all bearings and courses inserted in the log should be those shown by that compass alone; the binnacle compass being regarded solely as an approximate guide to the helmsman. When the ship has been placed on her proper course by the standard compass, the helmsman will notice the point shown by the binnacle compass as being that to which *he* has to attend; and a comparison of the two compasses should be frequently repeated by the officer of the watch or the quarter-master, and especially whenever the least alteration occurs in the direction of the course. When the ship is by the wind, the apparent course by the binnacle compass must, in like manner, be referred to the standard compass by direct and continual comparison; and the course made good by the latter is that which must be inserted in the log. In ships where a single binnacle compass is made to traverse, so as to be in front of the helmsman on each tack, it must be compared afresh with the standard compass at every such traverse, because the effect of the local attraction on the binnacle compass will have been altered by its change of place. In ships which have two permanently fixed binnacle compasses, the comparison with the standard must likewise be frequently repeated, both when the helmsman changes sides, and when the course steered is changed; for besides the alterations of local attraction produced by the ship's iron, to which the binnacle compasses are subject, they are often so near each other as to exercise a mutual attraction, and thus to induce a system of mutual errors, which are further involved by any change in the

Log board.

Comparison of standard and binnacle compasses.

direction of the ship's head,—thus occasioning a complication of errors for which the only safe or practical remedy is *a direct comparison on all occasions with the standard compass.*

Deviation of the binnacle compasses should be recorded,

During either of the processes for ascertaining the deviations of the standard compass, when the ship's head pauses at each point, it will be satisfactory to note, in a separate table, the corresponding directions of her head by the binnacle compasses. Should any temporary accident happen at sea to the standard, it should be recorded in the log-book.

and every day at noon.

It is also a useful practice at sea to compare every day, at *noon,* the direction of the ship's head by the binnacle compasses with that shown by the standard, on whatever course the ship may then be steering. This daily comparison will serve as a convenient check in working the reckoning, and may be thus entered in the log-book:—

Ship's Head at Noon.		
By Standard Compass.	By Port Binnacle Compass.	By Starboard Binnacle Compass.

Admiralty, 10*th March,* 1842.

TABLE I. (FORM FOR REGISTERING THE FIRST PROCESS.)

Observations to determine the Effect of the Ship's Iron on her Standard Compass, made in H. M. Ship Amethyst, on the 10th March, 1842, at Queen Hythe; Trinity Steeple distant, by estimation, twelve miles.

Real Magnetic Bearing of the Steeple from the Ship, N. 83° 0′ E.

Ship's Head by the Standard Compass.	Bearing of Steeple by the Standard Compass.	Deviation of the Standard Compass.
North.	N. 83° 11′ E.	0° 11′ W.
N. by E.	N. 82 7 E.	0 53 E.
N.N.E.	N. 81 20 E.	1 40 E.
N.E. by N.	N. 80 23 E.	2 37 E.
N.E.	N. 79 23 E.	3 37 E.
N.E. by E.	N. 78 33 E.	4 27 E.
E.N.E.	N. 77 38 E.	5 22 E.
E. by N.	N. 77 10 E.	5 50 E.
East.	N. 77 38 E.	5 22 E.
E. by S.	N. 78 3 E.	4 57 E.
E.S.E.	N. 78 26 E.	4 34 E.
S.E. by E.	N. 79 20 E.	3 40 E.
S.E.	N. 79 51 E.	3 9 E.
S.E. by S.	N. 80 30 E.	2 30 E.
S.S.E.	N. 81 18 E.	1 42 E.
S. by E.	N. 82 9 E.	0 51 E.
South.	N. 82 52 E.	0 8 E.
S. by W.	N. 83 55 E.	0 55 W.
S.S.W.	N. 84 38 E.	1 38 W.
S.W. by S.	N. 85 24 E.	2 24 W.
S.W.	N. 86 8 E.	3 8 W.
S.W. by W.	N. 86 50 E.	3 50 W.
W.S.W.	N. 87 39 E.	4 39 W.
W. by S.	N. 88 17 E.	5 17 W.
West.	N. 88 55 E.	5 55 W.
W. by N.	N. 88 35 E.	5 35 W.
W.N.W.	N. 88 8 E.	5 8 W.
N.W. by W.	N. 87 39 E.	4 39 W.
N.W.	N. 86 56 E.	3 56 W.
N.W. by N.	N. 86 9 E.	3 9 W.
N.N.W.	N. 85 31 E.	2 31 W.
N. by W.	N. 84 35 E.	1 35 W.

Note.—Deviation *East* signifies that the north end of the needle is drawn towards the east by the ship's attraction; deviation *West*, that the north end of the needle is drawn towards the west by the same cause. For example, in the latter case:—When the ship's head was N.W. the bearing of the steeple appears by the table to have been N. 86° 56′ E., though its real magnetic bearing (ascertained on shore) was N. 83° 0′ E.; it is therefore obvious, that the north end of the needle had been attracted 3° 56′ to the westward of its natural direction, and this error is consequently termed West Deviation. It is equally evident, that as long as the ship's head remains N.W. by her compass, so long must the course, and all the bearings *then* taken, be corrected by applying 3° 56′, or a third of a point, to the westward or left hand; the apparent N.W. course of the ship having been then really N.W. ⅓ W., and any bearing then taken, suppose N.N.E., being really N. by E. ⅔ E.

TABLE II. (FORM FOR REGISTERING THE SECOND PROCESS.)

Observations to determine the Effect of the Ship's Iron on the Standard Compass, made in H. M. Ship Amethyst, on the 10*th March,* 1842, *at Queen Hythe.*

The standard compass and the compass marked No. 33 were compared on shore by taking the bearing of a distant object with each compass, the two compasses being 12 feet apart. The bearings, by the means of several repetitions, were,—

By the Standard Compass....................................	N. 55° 0′ E.
By No. 33..	N. 55 30 E.
Difference to be applied to the bearings by No. 33	0 30

No. 33 being retained on shore, the standard compass was then replaced on board, and their mutual bearings from each other were simultaneously observed when the ship's head was successively on each of the thirty-two points, as follows:—

Time.	Ship's Head by the Standard Compass.	Bearing of the Shore Compass from the Standard Compass.	Bearing of Standard Compass from the Compass No. 33 on shore.		Deviation of the Standard Compass.
			Observed.	Corrected for the 30′ Difference of the Compasses.	
h m 9 10	North	S. 36° 11′ W.	N. 36° 30′ E.	N. 36° 0′ E.	0° 11′ W.
9 14	N. by E.	S. 34 7 W.	N. 35 30 E.	N. 35 0 E.	0 53 E.
9 17	N.N.E.	S. 32 20 W.	N. 34 30 E.	N. 34 0 E.	1 40 E.
9 21	N.E. by N.	S. 30 23 W.	N. 33 30 E.	N. 33 0 E.	2 37 E.
And in like manner at all the points of the compass.					

See Note appended to Table I.

TABLE III. (FORM FOR TABULATING THE RESULTS.)

Ship's Head, or Course, by the Standard Compass.	Deviation of the Standard Compass.	Correct Magnetic Course.
North	0° 11′ W	Nearly North
N. by E.	0 53 E	N 12° E
N.N.E.	1 40 E	N 24 E
N.E. by N.	2 37 E	N 36½ E
N.E.	3 37 E	N 48½ E
N.E. by E.	4 27 E	N 60½ E
E.N.E.	5 22 E	N 73 E
E. by N.	5 50 E	N 85 E
East	5 22 E	S 84½ E
E. by S.	4 57 E	S 74 E
E.S.E.	4 34 E	S 63 E
S.E. by E.	3 40 E	S 52½ E
S.E.	3 9 E	S 42 E
S.E. by S.	2 30 E	S 31½ E
S.S.E.	1 42 E	S 21 E
S. by E.	0 51 E	S 10 E
South	0 8 E	Nearly South
S. by W.	0 55 W	S 10 W
S.S.W.	1 38 W	S 21 W
S.W. by S.	2 24 W	S 31½ W
S.W.	3 8 W	S 42 W
S.W. by W.	3 50 W	S 52 W
W.S.W.	4 39 W	S 63 W
W. by S.	5 17 W	S 74 W
West	5 55 W	S 84 W
W. by N.	5 35 W	N 84½ W
W.N.W.	5 8 W	N 72½ W
N.W. by W.	4 39 W	N 60½ W
N.W.	3 58 W	N 49 W
N.W. by N.	3 9 W	N 37 W
N.N.W.	2 31 W	N 25 W
N. by W.	1 35 W	N 12½ W

To obtain the real magnetic course, or the real bearing of an object, from any course or bearing observed by the standard compass, look in the first column of the above Table for the apparent course, or for the point on which the ship's head was placed when the bearing was taken, and the deviation opposite thereto in the second column is the correction, to be applied in the following manner:—If the deviation is *east*, the correct magnetic bearing will be so much to the *right* of the compass bearing; if *west*, so much to the *left* of the compass bearing, supposing the eye to be looking from the centre of the compass towards the point to be corrected.

Form of the Deviation Table left on board H. M. Ships.

Whenever the officer in command may be superseded, this deviation table, and likewise any similar tables which may have been subsequently constructed from actual observations, in consequence of a change in the ship's geographical position, are to be carefully transferred to his successor, and a receipt taken for them.

THIS table is to be copied into the ship's log, and as it is indispensable that the change of deviation, according to the change of the ship's geographical position, should be ascertained (see paragraphs 10 and 11 of the "Practical Rules"), all observations for the reform of the table are likewise to be inserted therein.

After the ship shall have been swung, on her arrival upon a foreign station, and the deviations ascertained, two of the small blank forms supplied are to be filled up with the observations and their results, one of which is to be kept on board, and the other is to be transmitted to the Secretary of the Admiralty. The large form 1, is likewise to be filled up for use on board the ship.

A Table of the Deviations of the Standard Compass of H. M. S. of Guns, ascertained at

Name of Captain, or Officer in command.

Signature of Officer who superintended the Observations.

Name of Master.

Direction of Ship's Head by Standard Compass.	Deviation of Standard Compass.	Direction of Deviation.	Comparisons with Binnacle Compasses.		
			Direction of Ship's Head by Port Binnacle Compass.	Direction of Ship's Head by Central Binnacle Compass.	Direction of Ship's Head by Starboard Binnacle Compass.
North.					
N. by E.					
N.N.E.					
N.E. by N.					
N.E.					
N.E. by E.					
E.N.E.					
E. by N.					
East.					
E. by S.					
E.S.E.					
S.E. by E.					
S.E.					
S.E. by S.					
S.S.E.					
S. by E.					
South.					
S. by W.					
S.S.W.					
S.W. by S.					
S.W.					
S.W. by W.					
W.S.W.					
W. by S.					
West.					
W. by N.					
W.N.W.					
N.W. by W.					
N.W.					
N.W. by N.					
N.N.W.					
N. by W.					

Distance of Standard Compass.		ft.	in.
	From nearest gun........		
	" Tafrail		
	" nearest iron		
	" Iron davits		
	" Great funnel		
	" Binnacle compasses		
	" Spindle of capstan		
	Height of card from deck		

Should any alteration take place in the ship's armament, or iron work, in the vicinity of the compasses, the ship is to be swung again.

Steam Vessel. No. of H. P. of engines.						Sailing Ship.					
Armament.						Armament.					
Broadside Guns.		Bow.		Stern.		Poop.	Quarter Deck.	Fore-castle.	Main Deck.	Middle Deck.	Lower Deck.
Upper Deck.	Main Deck.	U. D.	M. D.	U. D.	M. D.						

NOTE.—When bearings are taken, the deviation should be applied as directed at page 5, example 2, of the "Practical Rules," according to the direction of the ship's head; and whenever practicable, azimuths should be observed on the course which the ship may be steering.

Experience having shown the *decrease* of deviation with the *decrease* of dip, that is, as we recede from either of the magnetic poles the deviation is lessened till it becomes *nil* at the magnetic equator, and changes the signs of + and − (or W. and E.) as the ship passes from one magnetic hemisphere to the other, such changes may therefore be expected to take place, but they should nevertheless always be proved by actual observation, as in cases where iron in the vicinity of the compasses is permanently magnetic, a difference to the above result would ensue.

With reference to the paragraphs 9 and 10 of the "Practical Rules," constant observation with the standard compass, on the course which the ship may be steering, cannot be too strongly recommended, and more particularly after any material change of the vessel's geographical position; for, although certain theories indicate a progressive diminution of deviation as we recede from either of the magnetic poles, till it becomes zero at the magnetic equator, and likewise involve a change of the signs + and – (or W. and E.) on passing from one magnetic hemisphere into the other; yet, as this would not altogether ensue if any of the iron in the vicinity of the compasses were permanently magnetic, continual observations should be resorted to as the safest guide.* There is also another circumstance which may be mentioned in this place, viz.: supposing even that none of the iron in the ship were permanently magnetic, yet, from the observations of the Antarctic Expedition, it would seem that a portion of time is necessary for the ship to attain the quality necessary to produce a direct change in the deviation, after crossing the magnetic equator;† and hence another motive for insisting upon perpetual observations.

The variation of the compass (or, as it is termed at the observatories, the "*magnetic declination*") having been for some years past constantly observed on land with delicately-constructed instruments in various parts of the world, and likewise on board ships where the deviations caused by their iron were known, and the results having been reduced to a given epoch, by the indefatigable labours of Colonel Sabine and the officers employed under him; from these, and numerous observations selected by Admiral Sir F. Beaufort, from the records in the Hydrographic Office, a variation chart, which will be of the greatest practical utility to mariners, has been constructed; for, independently of correcting a ship's course for *variation*, it will offer the means of ascertaining the amount of local attraction, or *deviation*, on any point of the compass on which the ship's head may be placed, by the simple means of observing and working an azimuth, and taking the difference between the result and the *correct* variation as the amount of *deviation;* and thus a ship may be swung at sea and the deviations ascertained on every point by observations on the sun only.

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* See also remarks upon the effect of portions of iron assuming the character of permanent magnets, the different degrees of hardness of that metal, &c. &c. in the "Observations on Magnetism," in this work.

† See remarks on this subject by Lieut.-Colonel Sabine, published in the "Philosophical Transactions," for 1846.

Again, in coast navigation, where the *true* bearings of lighthouses, churches, windmills, &c. &c. are known from each other, this variation-chart will afford the means of obtaining the *correct magnetic* bearings of such objects by correcting the variation up to the epoch required, and applying it to the *true* bearing; and hence, where there is sea room for a ship to be placed so as to bring any two of such objects in a line (and in a steam-ship this can be easily accomplished), the deviations on every point may be ascertained.

Besides the ordinary process of observing azimuths of the sun for correcting a ship's course, there are several other means which may be resorted to; such, for instance, as the plan mentioned by Mr. Henry Barrow, namely, that where a ship has chronometers on board and her position is known, the time of the moon or known stars passing that meridian being computable, the *true* course which the ship may be steering can be ascertained by measuring the angle between them and the ship's head, by means of the azimuth circle of the standard compass.*

The accompanying tables of the deviations of the compass, ascertained in different parts of the globe, by Captain (now Colonel) Sabine, and the late Captains Clavering and Forster in the northern regions, and the late Captain Basil Hall in the southern, together with those of Sir James C. Ross, during his late voyage, over so extensive a space (and with which he has kindly favoured me), will be a useful auxiliary to the preceding remarks; and are again inserted in this edition; and I may now (1851) add another table, showing the changes of deviation, according to the change of the ship's geographical position, which have been observed in some of her majesty's steam-ships since the first edition of this work was printed.*

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* See also Raper's "Practice of Navigation," page 313, third edition.

TABLES IX. AND X.

Deviations of the Compass ascertained on board H.M.S.

Direction of Ship's Head.	*Griper.*		*Conway*, in England and South America (1820).	
	England. Little Nore. Dip 70° 30′ N.	Spitzbergen, Hammerfast, 1823. Dip 77° 15′ N.	Portsmouth. Dip 70° 30′ N.	Valparaiso. Dip 38° 47′ S.
North	1° 4′ W	1° 30′ E	0° 7′ E	0° 37′ E
N.E.	10 26 E	19 30 E	2 43 E	0 26 W
East	13 36 E†	24 50 E	2 25 E	0 53 W
S.E.	9 36 E	18 30 E	1 6 E	0 16 E
South	1 56 E	4 0 E	1 57 W	0 29 E
S.W.	W†	12 25 W	3 15 E	0 24 E
West	13 34 W	24 10 W	4 5 E	1 2 E
N.W.	10 4 W†	16 45 W	1 39 W	0 50 W

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* As it has been erroneously asserted that the change of deviation, according to the change of the ship's geographical position, has not been taught in the system of compass observations ordered by the Board of Admiralty, particular attention is requested to paragraphs 10 and 11 of the "Practical Rules," in which it will be found that in every edition such change is not only insisted upon, but the means of ascertaining its amount is distinctly pointed out; and in addition to this, Tables IX., X., XI., showing the change of deviation which had taken place in some ships between England and Spitzbergen to the north, and between England and Valparaiso to the south, also between England, Porto Praya, St. Helena, Cape of Good Hope, and Kerguelen's Land, were actually printed in the first edition of this work (see pages 53 and 54), and copies of which are again inserted here.

While remarking upon this subject, we may also add that the system of observations practised at Greenhithe is not by placing marks in the magnetic meridian, but by simultaneous observations; or, in other words, precisely the process described at paragraphs 3, 4, 5, and 6 of the "Practical Rules."

† The deviations marked with a dagger (†) are the mean of two observations, one upon each side of the point.

TABLE XI.

Table of Deviations of the Compass of H.M.S. Erebus, in different parts of the World, as ascertained by Captain Sir James Clark Ross during his late Voyage.

Direction of Ship's Head.	Deviations of the Compass at				
	Gillingham, *Dip 69° 11′ N.	Porto Praya. Dip 45° 32′ N.	St. Helena. Dip 18° 16′ S.	C. of Good Hope. Dip 53° 7′ S.	Kerguelen's Land. Dip 70° 3′ S.
North	0° 6′ W	0° 56′ E	0° 4′ W	0° 24′ W	0° 8′ E
N. by E.	0 49 E	1 17 E	0 16 W	0 24 W	0 22 W
N.N.E.	1 39 E	1 53 E	0 28 W	0 1 W	1 1 W
N.E. by N.	2 16 E	2 12 E	0 51 W	0 11 W	1 31 W
N.E.	2 59 E	2 10 E	1 10 W	0 22 W	2 9 W
N.E. by E.	3 18 E	2 30 E	0 48 W	0 31 W	2 13 W
E.N.E.	3 46 E	2 47 E	0 57 W	0 51 W	3 1 W
E. by N.	4 53 E	2 40 E	0 55 W	1 2 W	3 31 W
East	3 42 E	1 56 E	0 32 W	1 15 W	3 48 W
E. by S.	3 17 E	1 44 E		1 34 W	3 53 W
E.S.E.	2 50 E	1 18 E	0 5 E	1 43 W	4 12 W
S.E. by E.	2 21 E	1 25 E	0 20 E	2 1 W	3 51 W
S.E.	1 53 E	1 9 E	0 20 E	1 53 W	3 20 W
S.E. by S.	1 23 E	0 25 E	0 25 E	1 41 W	2 50 W
S.S.E.	0 48 E	0 42 E	0 30 E	1 26 W	2 4 W
S. by E.	0 19 E	0 32 E	0 24 E	1 14 W	1 10 W
South	0 28 W	0 39 E	0 28 E	0 39 W	0 21 W
S. by W.	0 52 W	0 10 W	0 8 E	0 16 W	0 44 E
S.S.W.	1 34 W	0 2 E	0 1 E	0 2 E	1 53 E
S.W. by S.	2 8 W	0 9 W	0 14 W	0 40 E	2 33 E
S.W.	2 45 W	0 26 W	0 4 W	0 52 E	3 23 E
S.W. by W.	3 24 W	1 34 W	0 8 W	1 6 E	3 46 E
W.S.W.	4 3 W	1 24 W	0 9 W	1 5 E	4 5 E
W. by S.	4 40 W	1 49 W	0 12 E	1 14 E	3 56 E
West	4 19 W	1 33 W	0 32 E	1 9 E	3 40 E
W. by N.	4 9 W	1 15 W		0 51 E	3 35 E
W.N.W.	3 51 W	1 5 W	0 25 E	0 33 E	3 11 E
N.W. by W.	3 28 W	1 25 W	1 3 E	0 15 E	2 37 E
N.W.	3 3 W	1 15 W	0 40 E	0 3 E	2 1 E
N.W. by N.	2 30 W	0 52 W	0 33 E	0 2 W	2 7 E
N.N.W.	2 1 W	0 20 W	0 27 E	0 10 W	1 9 E
N. by W.	1 12 W	0 27 W	0 2 E	0 16 W	0 26 E
†Magnetic Intensity	1·000	0·840	0·591	0·715	1·068
	1·372	1·153	0·811	0·981	1·465

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* Westbourne Green.

† These values are expressed in terms of the two scales, of which one is the unit of intensity near London and the other in the north of Peru.

TABLE XIII.

Deviations of the Compass ascertained on board Three Iron Steam-Vessels in different Parts of the World.

Direction of Ship's Head by Standard Compass.	*Bloodhound.* Lieut. R. Phillipps.			*Jackal.* Lieut. W. M. Pasco.			*Trident.* Lieut. C. G. Rigge.	
	Plymouth Sound. 1845.	Near Constantinople. 1846.	Piræus of Athens. 1846.	Plymouth Sound. 1845.	River Tagus. 1847.	Piræus of Athens. 1846.	River Thames, Greenhithe. 1846.	Malta. 1847.
North	1° 0′ W	4° 20′ W	1° 45′ W	2° 15′ W	1° 0′ W	0° 40′ W	3° 12′ E	1° 19′ E
N. by E.	3 20 E	0 20 E	0 15 E	2 40 E	3 0 E	3 0 E	8 25 E	4 29 E
N.N.E.	7 15 E	4 0 E	2 55 E	8 58 E	6 40 E	6 30 E	13 44 E	6 59 E
N.E. by N.	10 50 E	7 0 E	7 15 E	13 7 E	9 20 E	8 20 E	18 37 E	11 19 E
N.E.	13 20 E	9 0 E	8 35 E	15 18 E	11 20 E	10 40 E	21 7 E	14 9 E
N.E. by E.	14 40 E	10 20 E	10 20 E	17 15 E	12 20 E	11 20 E	21 45 E	14 59 E
E.N.E.	15 0 E	11 20 E	11 0 E	18 7 E	12 0 E	12 20 E	22 15 E	15 29 E
E. by N.	15 0 E	11 50 E	9 55 E	17 47 E	12 0 E	10 30 E	22 26 E	14 29 E
East	14 0 E	12 50 E	9 15 E	15 35 E	11 40 E	10 0 E	20 18 E	13 19 E
E. by S.	13 20 E	10 30 E	8 5 E	14 38 E	10 20 E	9 0 E	18 50 E	12 9 E
E.S.E.	11 50 E	9 0 E	6 35 E	13 22 E	9 20 E	8 0 E	16 30 E	10 9 E
S.E. by E.	10 20 E	6 50 E	5 35 E	11 40 E	9 0 E	6 15 E	13 0 E	9 9 E
S.E.	9 20 E	5 30 E	4 15 E	9 55 E	5 40 E	4 0 E	11 0 E	7 9 E
S.E. by S.	7 50 E	3 0 E	3 15 E	8 5 E	4 40 E	3 15 E	7 30 E	6 9 E
S.S.E.	6 20 E	2 50 E	2 55 E	5 35 E	3 20 E	3 0 E	6 0 E	4 59 E
S. by E.	4 20 E	2 40 E	2 35 E	4 12 E	2 40 E	1 20 E	2 20 E	3 39 E
South	2 40 E	2 20 E	2 45 E	2 20 E	2 0 E	0 40 E	0 6 W	2 29 E
S. by W.	1 20 E	1 30 E	1 15 E	0 12 W	1 20 E	1 0 W	2 45 W	0 19 E
S.S.W.	0 50 W	0 40 E		2 32 W	1 0 W	1 20 W	5 58 W	1 21 W
S.W. by S.	2 40 W	0 10 W	1 35 E	4 55 W	1 0 W	2 40 W	8 42 W	2 51 W
S.W.	5 20 W	2 40 W	0 5 W	6 30 W	3 40 W	2 40 W	10 55 W	5 1 W
S.W. by W.	7 10 W	4 0 W	1 55 W	8 45 W	4 0 W	4 40 W	13 25 W	7 21 W
W.S.W.	9 50 W	6 0 W	3 45 W	10 52 W	7 40 W	5 40 W	17 10 W	9 31 W
W. by S.	11 10 W	7 30 W	7 5 W	13 50 W	10 0 W	8 20 W	19 17 W	10 41 W
West	13 0 W	10 0 W	9 5 W	15 45 W	12 40 W	9 40 W	20 35 W	12 51 W
W. by N.	15 50 W	11 20 W	11 45 W	17 25 W	13 20 W	11 20 W	21 22 W	14 21 W
W.N.W.	16 40 W	12 30 W	13 5 W	18 25 W	15 20 W	12 0 W	21 12 W	14 21 W
N.W. by W.	16 40 W	11 20 W	12 25 W	18 25 W	15 0 W	12 40 W	19 40 W	15 1 W
N.W.	15 30 W	12 30 W	10 45 W	17 15 W	14 40 W	11 5 W	18 15 W	14 21 W
N.W. by N.	13 30 W	11 0 W	9 30 W	15 45 W	14 40 W	9 40 W	14 40 W	11 31 W
N.N W.	11 20 W	8 30 W	8 45 W	11 55 W	9 20 W	8 0 W	9 38 W	8 41 W
N. by W.	6 0 W	6 20 W	5 0 W	7 25 W	5 40 W	4 30 W	3 50 W	4 21 W

With respect to the change in the amount of deviation which has taken place in some iron ships, according to their change of geographical position, the preceding table may serve to show, although it should be remembered that the results obtained in one iron vessel ought not to be considered as an infallible guide to those which may take place in another; indeed, there is so much information yet required on this subject, that at present any further remarks than those insisting upon constant observation would be out of place here.

For the purpose of ascertaining any change which may take place in the magnetism of an iron ship, besides that denoted by the *deviations*, it would be very desirable that vertical vibrations with the dipping needle, and horizontal vibrations with Hansteen's magnetic intensity instrument, placed in the same position as the standard compass, should be observed in different parts of the world.

SUPPLEMENT TO TABLES XI. AND XIII.

A Table showing the Deviations of the Compass in some of H.M. Steam-ships in different parts of the World.

Direction of Ship's Head by Standard Compass.	*Centaur.* Capt. Buckle. Commo. Fanshawe		*Geyser.* Commander Brown.		*Sphynx.* Comm. Shadwell.		*Acheron.* Capt. Stokes.		*Cormorant.* Com. Schomberg.	
	England, 1849.	Fernando Po, Coast of Africa, 1850.	England, 1847.	Cape of Good Hope, 1850.	England, 1848.	Hong Kong, 1851.	England, 1847.	New Zealand, Port Nicholson, 1850.	England, 1849.	South America, Bahia, 1851.
	Dev.	Dev.	Dev.	Dev.	Dev.	Dev.	Dev.	Dev.	Dev.	Dev.
North	2° 20′ E	1° 55′ E	2° 0′ W	1° 50′ W	0° 20′ E	2° 1′ W	3° 0′ E	0° 12′ W	4° 15′ E	1° 0′ E
N. by E.	3 40 E	3 30 E	0 0	2 10 W	2 10 E	0 50 E	4 40 E	1 19 W	7 0 E	3 0 E
N.N.E.	5 40 E	3 0 E	2 20 E	2 30 W	5 20 E	0 40 E	6 35 E	1 20 W	8 5 E	3 50 E
N.E. by N.	6 50 E	3 30 E	4 30 E	2 15 W	7 50 E	2 0 E	8 15 E	0 54 W	9 30 E	3 40 E
N.E.	8 0 E	4 10 E	6 50 E	2 0 W	8 50 E	2 0 E	8 35 E	1 1 W	11 5 E	4 40 E
N.E. by E.	8 10 E	4 40 E	7 20 E	1 50 W	10 0 E	1 0 E	8 40 E	0 32 E	11 25 E	5 35 E
E.N.E.	7 20 E	4 50 E	7 50 E	1 40 W	10 0 E	0 20 E	8 50 E	2 57 E	10 10 E	3 0 E
E. by N.	7 35 E	3 30 E	9 50 E	2 35 W	9 50 E	0 50 E	8 30 E	1 57 E	10 5 E	1 40 E
East	6 40 E	2 10 E	9 10 E	3 30 W	9 20 E	3 30 E	8 10 E	1 54 E	8 0 E	0 20 E
E. by S.	5 40 E	1 30 E	9 10 E	3 30 W	8 40 E	0 45 E	7 5 E	2 52 E	5° 0 E	0 20 E
E.S.E.	4 40 E	0 10 W	9 10 E	3 30 W	7 20 E	1 30 E	5 45 E	3 21 E	3 55 E	0 10 W
S.E. by E.	3 40 E	0 30 W	7 40 E	3 15 W	6 10 E	0 40 E	4 25 E	3 55 E	2 15 E	1 10 W
S.E.	2 0 E	1 30 W	6 30 E	3 0 W	4 30 E	1 20 E	3 0 E	3 51 E	1 15 E	1 40 W
S.E. by S.	1 0 E	1 20 W	5 30 E	1 45 W	3 40 E	1 0 W	1 40 E	3 52 E	0 35 W	2 20 W
S.S.E.	0 30 W	1 30 W	4 40 E	0 30 W	2 20 E	1 0 W	1 0 E	3 52 E	1 55 W	2 15 W
S. by E.	1 30 W	1 10 W	3 0 E	0 25 W	1 0 E	1 5 W	1 5 W	3 38 E	3 50 W	1 55 W
South	2 45 W	2 30 W	1 40 E	0 20 W	0 40 W	1 10 W	2 10 W	1 25 E	4 5 W	1 30 W
S. by W.	3 50 W		0 0	0 55 E	2 0 W	1 0 W	3 40 W	1 19 E	4 0 W	1 40 W
S.S.W.	5 20 W	1 30 W	1 0 W	2 10 E	2 50 W	1 50 W	4 5 W	1 10 E	4 30 W	2 20 W
S.W. by S.	6 0 W	1 35 W	2 20 W	2 20 E	3 40 W	1 25 W	4 57 W	1 30 E	6 20 W	0 50 W
S.W.	6 30 W	1 45 W	3 30 W	2 30 E	4 20 W	1 50 W	5 50 W	2 10 E	7 15 W	0 50 W
S.W. by W.	7 30 W	2 20 W	5 0 W	2 20 E	5 20 W	2 15 W	6 0 W	1 32 E	7 20 W	0 40 W
W.S.W.	7 40 W	2 20 W	6 30 W	2 10 E	6 30 W	1 40 W	7 20 W	0 43 W	8 20 W	0 40 W
W. by S.	8 10 W	3 10 W	8 0 W	1 40 E	7 30 W	2 0 W	7 20 W	0 49 W	7 0 W	1 40 W
West	8 0 W	2 30 W	9 20 W	1 10 E	8 30 W	2 25 W	7 5 W	0 13 W	7 15 W	1 55 W
W. by N.	7 40 W	2 20 W	10 20 W	0 30 E	8 40 W	2 50 W	6 35 W	0 4 W	7 5 W	2 25 W
W.N.W.	6 40 W	2 20 W	10 0 W	0 10 W	8 40 W	4 0 W	6 10 W	0 58 W	6 55 W	3 0 W
N.W. by W.	5 40 W	2 20 W	11 0 W	0 35 W	8 20 W	4 0 W	5 30 W	1 8 W	6 40 W	3 0 W
N.W.	4 30 W	2 10 W	9 40 W	1 0 W	7 50 W	3 50 W	4 25 W	0 8 W	4 10 W	2 50 W
N.W. by N.	3 10 W	1 20 W	8 20 W	0 45 W	6 10 W	3 40 W	3 3 W	0 42 W	2 30 W	2 0 W
N.N.W.	1 50 W		6 0 W	0 30 W	4 30 W	1 50 W	1 40 W	1 32 W	1 35 W	0 40 W
N. by W.	0 40 E	1 20 E	4 40 W	1 10 W	2 0 W	2 0 W	0 20 E	0 12 W	0 30 E	0 20 W

Having already explained several practical methods of ascertaining the deviation and its changes, it is proper that I should notice in this place two ingenious pamphlets which have been printed on the subject, since the first edition of this work was published. One is entitled "Directions for the Use of a small Apparatus to be employed with a Ship's Standard Compass, for the purpose of ascertaining at any time, whether at sea or in harbour, the changing part of the Deviation in the pointing of the Compass by the Ship's Iron, or that part of the Deviation which is usually different in different parts of the Globe. By Lieut.-Colonel Edward Sabine, R.A."

The apparatus itself is simply a brass bar with grooves at the top, capable of receiving and clamping small magnets at given distances from the centre; which centre is so arranged, that it may fit very exactly the centre of the azimuth circle of a standard compass.

The process of swinging the ship is necessary, in the first instance, to ascertain the deviations, in order that the *resultant points* (so termed) may be discovered, as it is on these points the ship's head is to be steadied while the magnets are applied to deflect the compass-needle.

As the manner of using these magnetic deflectors and the application of the results are fully described in the pamphlet, it is only necessary to observe in this place, that the computations are made by means of three "permanent" coefficients, so termed, the process of swinging the ship, in the first instance, supplying the data from which their values are obtained for any particular ship;* and the same process

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* The manner of calculating these coefficients is pointed out in the "Manual for Scientific Inquiry."

Among the notes of Archibald Smith, Esq. I find the following remarks on these deflectors:—

"The disturbing effect of the ship's iron affects not only the direction in which the needle points, but also the force with which it is retained in that direction; and the following relation exists between the two effects, viz.: the difference of the values of the horizontal force observed when the ship's head which supplies the data from whence the *permanent* coefficients are derived, furnishes also data for computing the *changing* coefficient.

The pamphlet contains Tables of Corrections to be used on account of the coefficients, and likewise examples of the method of working out the deviations arithmetically. Some of these deflecting instruments are on trial at the present time in different ships.

The other ingenious pamphlet referred to is entitled "Instructions for the Computation of a Table of the Deviations of a Ship's Compass, from Deviations observed on 4, 8, 16, or 32 Points; and for the Adjustment of the Table on a change of Magnetic Latitude. By Archibald Smith, Esq. M.A., late Fellow of Trinity College, Cambridge."

> "The principal object of the present instructions (Mr. Smith observes) is to enable the navigator, where it is inconvenient or impossible to swing his ship on thirty-two or sixteen points, as has hitherto been usually done, to obtain a Table of Deviations from observations on eight or even upon four points."

The method employed is that which is known to mathematicians as the method of least squares, and the computations are made by the aid of five coefficients, A, B, C, D, and E, for computing the value of which full explanations are given, together with tables and examples for working out the deviations.

It is necessary to remark, that where observations are made on the smallest number of points mentioned, those selected should not be the four cardinal points, but N.W.,

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is placed successively on the north and south *resultant points*, divided by their sum, is equal to the sine of the deviation on the east and west resultant points."

This relation he (Mr. S.) observed, and proposed to make use of it as a method of determining the maximum coefficient of deviation. (See Sabine's contributions to "Terrestrial Magnetism," Nos. v. and viii.)

"This method was first practised by Lieut. Henry Clark, R.A., who ingeniously determined the values of the horizontal force by deflecting the compass-needle by means of a magnet." (See Sabine's "Contributions," No. viii.)

S.W., S.E., and N.E., and that it is indispensable that these few observations should be made with the greatest care and with the most accurate instruments, otherwise errors of importance might accrue.

It is only justice to Mr. A. Smith, who has bestowed so much time and labour on magnetic subjects, to mention in this place the close approximation of his theories with the actual observations referred to in his pamphlet.

1851. It having been already stated that the deviations in one iron ship are no guide to their amount or direction in another,* the following Table of Deviations of her majesty's steam-vessel Bloodhound, ascertained at different periods in England, will show that the remark may be extended to the permanency or otherwise of their magnetism; for in the case of the Birkenhead (see Table I. page 36), the changes in the course of three years appear to be so small as to be rather attributable to the nature of compass observations than to a change in the ship's magnetism; yet, in the case of the Bloodhound (where, after due inquiry in the different departments, I found that no change had been made in her armament, boilers, machinery, or iron-work generally, nor in her rig), the difference in the results of the last two series of observations seems sufficiently marked to indicate some alteration in the ship's magnetism; and it adds another proof (if indeed such a repetition be required) of the necessity for continual observations, whether the compasses have their deviations reduced by magnets and iron, or not.

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* By the different Tables in this work, it will be seen that, in some iron ships, when their heads were to the westward, the deviation was easterly, and when their heads were to the eastward, the deviation was westerly, while in others precisely the reverse of this occurred. This sometimes arises from the different position of their compasses with respect to the iron of the ship: but I may mention in this place a curious fact with respect to the *binnacle*-compasses of two iron steam-vessels, which occupy very nearly the same relative position in both, namely, in the central fore-and-aft line of the ship in front of the wheel.

At page 27 it has already been mentioned, that in the Onyx the direction of the binnacle-compass was almost reversed; that is, when the vessel's head was actually north (correct magnetic), the said compass indicated it to be S.E.; while, in the Princess Alice, the binnacle-compass proved to be nearly correct on every point, in a similar position.

A Table of the Deviations of the Standard Compass of H. M. Steam Vessel Bloodhound, ascertained in England at different periods.

Direction of Ship's Head by Standard Compass.	Deviation of Standard Compass. Greenhithe, 1847.	Deviation of Standard Compass. Plymouth, 1851.
North.	1° 0′ W	5° 0′ W
N. by E.	2 40 E	2 10 W
N.N.E.	6 12 E	2 0 E
N.E. by N.	9 10 E	5 20 E
N.E.	11 10 E	7 0 E
N.E. by E.	12 0 E	6 50 E
E.N.E.	12 47 E	7 50 E
E. by N.	11 40 E	8 30 E
East.	11 47 E	10 0 E
E. by S.	10 27 E	9 0 E
E.S.E.	9 25 E	8 40 E
S.E. by E.	8 20 E	6 20 E
S.E.	7 20 E	6 0 E
S.E. by S.	6 30 E	4 40 E
S.S.E.	5 20 E	2 40 E
S. by E.	3 37 E	1 50 E
South.	3 0 E	0 50 W
S. by W.	1 50 E	1 40 W
S.S.W.	0 25 W	2 10 W
S.W. by S.	1 50 W	4 20 W
S.W.	4 0 W	6 30 W
S.W. by W.	5 40 W	10 40 W
W.S.W.	7 52 W	11 20 W
W. by S.	9 37 W	12 20 W
West.	11 24 W	14 50 W
W. by N.	12 37 W	15 50 W
W.N.W.	13 0 W	16 50 W
N.W. by W.	13 15 W	16 30 W
N.W.	12 45 W	16 20 W
N.W. by N.	11 25 W	14 30 W
N.N.W.	8 10 W	12 0 W
N. by W.	4 27 W	10 0 W

Observers, Capt. Johnson and Mr. Thompson.

Bearing-Plates.

In steam-ships much inconvenience is frequently experienced in taking bearings of lights or land-marks from the standard compass in its proper position, in consequence of the view being impeded on many points by the great funnel and paddle-boxes, and as serious errors accrue when a compass is moved from one part of a ship to another for the purpose of taking bearings, in consequence of the different effects of the iron, according to its position (see page 65), an instrument of small expense, which I have termed a " bearing-plate," has been constructed under my direction to obviate the evil.

The bearing-plate is simply a circular plate of brass (or it may be zinc or copper) on which the points, and the half and quarter points of the compass, are engraved (but not lettered), the circumference being graduated, and having the two zeros opposite to each other, and 90° marked at right angles.

A brass bar capable of a circular movement is attached at the centre of the plate, like that of a circumferenter with a nonius, a perpendicular vane being fixed to each end.

A double joint underneath the plate, and fitted to an oblong square stem, enables the observer to level the instrument sufficiently near by the eye, for the practical purpose contemplated, the joint affording two vertical motions, one fore and aft, and the other athwart-ships.

Two or three sockets, or oblong troughs, are made very exactly to suit the stem, and so that they may be let into the wood and fixed in any part or parts of the ship, which may be found most convenient for taking bearings; as, for instance, on the paddle-boxes, the tafrail, or forecastle, &c.

Be it observed that, before fixing the sockets, great care must be taken in adjusting them in the line of the keel or parallel to it (according to the position selected), when the vanes of the plate are set to the zeros, and representing that line.

The stem of the bearing-plate being so constructed that it will only fit one way into the socket, and that while the zeros are accurately in the fore-and-aft line, no further adjustment in this respect is required at the time of observation. It can, of course, be moved from one socket to another at pleasure, or be taken away altogether, as circumstances may require.

By means of the above-mentioned contrivance, it will be obvious to the practical navigator that the angle between any objects, lights, land-marks, &c., and the ship's head, may be measured at any time within small limits of error; and hence, by applying that angle to the direction of the ship's head, as indicated at the moment by the standard compass and corrected for deviation, the *correct* magnetic bearing of such objects may be obtained, and which is of the highest importance when navigating intricate channels.*

In very high latitudes, where the dip is great, and the compass becomes useless, the azimuth circle of the standard compass, and likewise the bearing-plate, will be useful appendages for regulating the ship's course by means of the observed angles between the ship's head and the heavenly bodies, and which cannot always be conveniently accomplished by means of the sextant.†

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* A small copper hand lamp is all that is required for "reading off" the measured angle at night.

† The ships of the Arctic Expedition, under the command of Captain Austin, and now in search of the missing expedition of Sir John Franklin, were supplied with bearing-plates by order of the Lords Commissioners of the Admiralty. These plates were made by Mr. West, and that for the Victoria and Albert by Mr. Dennis.

Influence of Iron "Diagonal Riders" upon the Compasses.

Having, in the course of my duties, frequently observed large differences between the port and starboard binnacle compasses of several of her majesty's steam-vessels, and likewise a greater difference than seemed to be accounted for by position between these and the standard compass, I have lately been led to inquire whether an unusual quantity of iron may not have been introduced into the sides of these vessels during their construction; and from the drawing which has been officially forwarded to me of one of them, in which all portions of iron are distinguished from wood, there seems little reason to doubt but that the wrought-iron diagonal riders in the sides would fully account for such discrepancies in the compass observations. And as a warning against carrying these iron diagonal riders (supports as they may be) higher than is absolutely necessary, or, indeed, under any circumstances, nearer than twenty feet of any of the compasses, the following particulars relating to her majesty's ship Conflict are inserted; which vessel, be it observed, had neither her engines nor great funnel on board, but was at the time navigated as a sailing-vessel.

Mr. Mills, Assistant-master-attendant, having experienced considerable difficulty in navigating the Conflict from Milford, in consequence of the great difference observed in the direction of the ship's head, as indicated by the port and starboard binnacle compasses, resorted to the measure of placing a compass thirteen feet above the deck, and then comparing the other compasses with it. After reporting the circumstance on his arrival in Plymouth Sound, the Conflict was swung, and the following results were obtained:—

Direction of Ship's Head by a Compass 13 feet above the Deck.	Direction of Ship's Head by Port Binnacle Compass.	Direction of Ship's Head by Starboard Binnacle Compass.	Direction of Ship's Head by a Compass 13 feet above the Deck.	Direction of Ship's Head by Port Binnacle Compass.	Direction of Ship's Head by Starboard Binnacle Compass.
North	N ¾ E	N ¼ W	South	S ¾ E	S by W
N. by E.	N by E ¾ E	N ¾ E	S. by W.	S ½ W	SSW ¼ W
N.N.E.	NE by N ¼ N	NNE	S.S.W.	S by W ½ W	SW by S
N.E. by N.	NE ½ N	NE by N ¼ N	S.W. by S.	SW by S ½ S	SW ¼ S
N.E.	NE ¼ E	NE ½ N	S.W.	SW ¼ W	SW by W
N.E. by E.	NE by E	NE ¼ E	S.W. by W.	SW ½ W	SW by W ¼ W
E.N.E.	ENE	NE by E ¼ E	W.S.W.	W by S ¾ S	W by S ½ S
E. by N.	E by N	E by N ¾ N	W. by S.	W ½ S	W ½ S
East	E ¼ N	E ¼ N	West	W ½ N	W ¼ N
E. by S.	E ½ S	E ¾ S	W. by N.	W by N ¾ N	W by N ¼ N
E.S.E.	E by S ½ S	ESE ¼ E	W.N.W.	NW by W ¼ W	WNW
S.E. by E.	SE by E ½ E	SE ½ E	N.W. by W.	NW ¼ W	
S.E.	SE ¾ E	SE ¼ S	N.W.	NW ¾ N	NW ¼ N
S.E. by S.	SE ¼ S	SE by S ½ S	N.W. by N.	NW by N ¾ N	NW ¾ N
S.S.E.	SE by S	S by E ½ E	N.N.W.	N by W ¼ W	NW by N ¾ N
S. by E.	S by E ¾ E	S ¼ E	N. by W.	N ¼ W	N by W ½ W

On this vessel's arrival at Woolwich, the late Mr. Elson, Master-attendant, accompanied me on board, and having placed compasses on different parts of the deck, we were fully convinced of the great amount of local attraction exerted upon them, which was much increased on changing their position nearer to the ship's sides.

It appears quite evident from the case of the Conflict, that if malleable iron in bars be introduced into the ship's sides or deck in the vicinity of the compasses, that the difficulty of navigating such vessels will be as great as that which exists in iron vessels.

In ships of war the effect of any undiscovered portion of iron upon the compasses is, according to the system now adopted, made apparent during the process of swinging; but in merchant-vessels, should the wrought-iron diagonal riders be adopted, there would be more danger, inasmuch as there would probably be less suspicion of the effect of such appliances.

Subsequent experiments on board the Encounter at Deptford fully confirm the preceding remarks, and although, in that vessel, the iron "diagonal riders" did not come so high as those in the Conflict, yet the following facts were elicited, viz. that when the riders were connected by means of a curved bar riveted to them, according to the suggestion of the late Lord John Hay, the deviations of the compass were lessened; and, although not to any considerable amount, yet enough was elicited to confirm the idea that, so far as the compass question is concerned, curved iron riders, in the shape of horse-shoes, with their ends placed downwards in the manner proposed by his lordship, would lessen their polarity, and thereby weaken their influence upon the compass.

It is necessary to observe, however, that the polarity of the riders had not been destroyed in this case, inasmuch as when a compass needle was approached near to their ends at the place of junction with the curved bars, the south pole was invariably repelled and the north pole attracted; and that effect was elicited whether the needle were placed above or below the end of the rider, or inside or outside of the ship.

Following up the evidence respecting the influence of the iron diagonal riders upon the compass, I selected from the records of compass observations in my possession the names of five vessels, wherein the deviations of the standard compass were small, considering their size and armament, and five others in which the deviations were large, under similar or nearly similar circumstances; and this without knowing anything of their peculiar constructions.

On application to Mr. Edye, he readily gave me access to such plans of the vessels as were in his office, and Mr. Lang and Mr. Wilcox favoured me with the inspection of the others.

The following was the result of the examination of the several plans:—In the five vessels having small deviations, *two* of them had no iron diagonal riders, *one* had iron riders 2¾ feet above the *lower* deck, *one* had iron riders which only came up to the *lower* deck, and *one* had iron riders 2½ feet below the quarter-deck. While in the five vessels having large deviations, *two* of them had iron riders up to the *quarter*-deck, *one* had iron riders projecting 3 inches *above* the *quarter*-deck, and *two* had iron riders 2¾ feet below the *quarter*-deck.

Some difference of effect would necessarily be produced by distance, according to the breadth of the several vessels; but taking all the circumstances into consideration, there remains no doubt, but that when the ends of these iron riders project above the level of the lower deck, they augment the deviations very materially; and, therefore, it is desirable that they should be kept as low down as may be practicable, and in the curved form before described, and that they should never project above the level of the lower deck within a radius of twenty feet of the compasses.

From the very marked effect of long bars of wrought-iron upon the compass, it is further desirable, in addition to the former regulations on the subject, that all davits, *large* stanchions, &c. within the above-named distance, should be made of wood or mixed metal, and the same as respects the knees under the quarter-deck abreast of the binnacles.

In vessels wherein the diameter of the wheel is small, such as steam-vessels and sloops of war, &c., it is by far the most judicious plan, as has already been observed, to place the binnacle compass in the centre line of the ship, a couple of feet in front of the wheel, in which position the influence of the diagonal riders in the steamers will be lessened, and likewise that of the guns in the sloops, besides the advantage of assimilating, in some degree, the deviations of the binnacle to those of the standard compass; and more particularly as the only objection to this plan, viz. the parallax between the lubber line and card (arising from the helmsman standing out of the line passing over the centre of the compass and lubbers' point), will be nearly annihilated when a sufficient number of binnacle compasses on the same plan as the standard, and having the margin of the card near to the bowl, shall have been constructed.

1850. Proceeding with the further evidence respecting the influence of the iron diagonal riders upon the compass, which has been elicited since the first edition was printed, we may now request attention to the following Tables of the *deviations* of the Conflict and Encounter when armed, the latter vessel having had the iron diagonal riders shortened and connected in the manner before described, while those of the Conflict remained as previously mentioned.* The results are entirely confirmatory of the views formerly expressed on the subject, showing in a very marked manner the advantage of shortening the iron "riders" in the vicinity of the compasses; for the *deviations* of the Encounter, it will be perceived, are reduced to nearly one-half the amount of those of the Conflict, while in the latter ship they are actually greater than in some iron vessels. These remarks, we may observe, are equally applicable to sailing ships as to steam-vessels.

Comparison of the Deviations of the Standard Compasses of Her Majesty's Steam-ships Encounter and Conflict.

SUPPLEMENT TO TABLE OF CONFLICT'S DEVIATIONS, PAGE 113.

Direction of Ship's Head.	*Encounter.*	*Conflict.*	Direction of Ship's Head.	*Encounter.*	*Conflict.*
	Deviation of Stand. Compass.	Deviation of Stand. Compass.		Deviation of Stand. Compass.	Deviation of Stand. Compass.
North	2° 10′ W	1° 0′ W	South	0° 30′ E	1° 40′ E
N. by E.	0 40 W	4 0 E	S. by W.	0 10 W	0 30 W
N.N.E.	2 20 E	7 0 E	S.S.W.	0 40 W	4 40 W
N.E. by N.	3 40 E	10 0 E	S.W. by S.	2 0 W	6 45 W
N.E.	4 50 E	13 0 E	S.W.	3 40 W	9 50 W
N.E. by E.	5 10 E	14 35 E	S.W. by W.	4 40 W	10 40 W
E.N.E.	5 20 E	15 0 E	W.S.W.	5 0 W	11 0 W
E. by N.	5 40 E	15 40 E	W. by S.	6 20 W	11 30 W
East	6 0 E	15 30 E	West	7 10 W	12 30 W
E. by S.	7 0 E	14 54 E	W. by N.	7 20 W	14 30 W
E.S.E.	7 20 E	12 40 E	W.N.W.	8 20 W	14 0 W
S.E. by E.	7 10 E	10 15 E	N.W. by W.	8 20 W	13 0 W
S.E.	6 20 E	10 0 E	N.W.	9 0 W	10 55 W
S.E. by S.	5 50 E	8 30 E	N.W. by N.	7 10 W	9 40 W
S.S.E.	2 50 E	6 0 E	N.N.W.	6 20 W	6 10 W
S. by E.	1 20 E	4 15 E	N. by W.	5 30 W	3 20 W
	Observer, Mr. Thompson.	Observer, Mr. Walker.		Observer, Mr. Thompson.	Observer, Mr. Walker.

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* The guns of the Conflict in the vicinity of the compasses have been since moved from the places they occupied in 1849; and when the ship was swung again by Mr. (now Commander) Walker, R.N., the results showed a very considerable difference in the deviations, and confirm the opinion so frequently insisted upon in these pages of the necessity for reswinging the ship whenever any such alterations are made.

Remarks on the Effect which the heeling of a Ship produces upon the Deviations.

This additional source of error was noticed many years ago; the subject is also mentioned by the Astronomer Royal in the "Philosophical Transactions," 1839, and has likewise been treated of by Lieut. Raper (1840) in his "Practice of Navigation." The portion of error, however, produced by heeling in timber-built ships, when the compass is considerably elevated above the level of the guns, &c., (for instance, upon the poop of ships of the line, due care being taken to remove small portions of iron from its vicinity,) does not appear to be of such amount as to be of importance in practice.

This was found to be the case on board her majesty's ship St. Vincent, 120 guns, which ship, in September 1844, was heeled eight degrees by means of 100 tons of water and the weight of her crew (1000 men), the proper observations for ascertaining the deviations having been made both when the ship was in an upright and in an inclined position; but, with respect to iron vessels, it must not be overlooked that Mr. Walker has shown, by observations on board her majesty's iron brig Recruit, Commander A. Slade, that the heeling of the vessel affected the deviations of the binnacle compass to a very considerable amount. The results obtained by Commander Strange on board the same vessel, proved the standard compass, which was elevated about eighteen inches above the level of the iron-top sides, to be likewise affected, but in a less degree; and the following table of results, deduced from observations made on board her majesty's iron steam-vessel Bloodhound, Lieut. Phillipps (which vessel the Lords Commissioners of the Admiralty placed under my directions at Greenhithe), will serve to illustrate this branch of the subject, and inculcate the necessity of ascertaining the deviations in all iron sailing ships, both when upright and inclined.

TABLE XII.

*Results deduced from Observations made on board Her Majesty's Iron Steam-vessel Bloodhound.**

Direction of Ship's Head by Standard Compass.	Fires extinguished.	Fires lighted and Steam up.		Fires extinguished.				
				Ship heeled 8 degrees to Port.		Ship upon an even Keel.	Ship heeled 8 degrees to Starboard.	
	Deviation of Standard Compass.	Deviation of Standard Compass.	Diff.	Deviation.	Diff.	Deviation.	Deviation.	Diff.
North	1° 0′ W	0° 37′ W	0° 23′	4° 30′ W	3° 30′	1° 0′ W	0° 25′ E	1° 25′
N. by E.	2 40 E	2 50 E	0 10	1 2 W	3 42	2 40 E	3 40 E	1 0
N.N.E.	6 12 E	6 13 E	0 1	2 37 E	3 35	6 12 E	7 30 E	1 18
N.E. by N.	9 10 E	9 18 E	0 8	6 0 E	3 10	9 10 E	9 50 E	0 40
N.E.	11 10 E	11 7 E	0 3	8 40 E	2 30	11 10 E	11 55 E	0 45
N.E. by E.	12 0 E	11 48 E	0 12	10 10 E	1 50	12 0 E	13 15 E	1 15
E.N.E.	12 47 E	11 55 E	0 52	11 25 E	1 22	12 47 E	13 0 E	0 13
E. by N.	11 40 E	12 30 E	0 50	11 40 E	0 0	11 40 E	12 45 E	1 5
East	11 47 E	11 35 E	0 12	11 5 E	0 42	11 47 E	10 50 E	0 57
E. by S.	10 27 E	11 10 E	0 43	10 55 E	0 28	10 27 E	10 5 E	0 22
E.S.E.	9 25 E	9 20 E	0 5	10 10 E	0 45	9 25 E	8 0 E	1 25
S.E. by E.	8 20 E	8 40 E	0 20	9 30 E	1 10	8 20 E	6 15 E	2 5
S.E.	7 20 E	7 20 E	0 0	8 57 E	1 37	7 20 E	4 50 E	2 30
S.E. by S.	6 30 E	6 20 E	0 10	7 55 E	1 25	6 30 E	2 5 E	4 25
S.S.E.	5 20 E	5 5 E	0 15	7 10 E	1 50	5 20 E	1 27 E	3 53
S. by E.	3 37 E	4 25 E	0 48	6 5 E	2 28	3 37 E	0 50 W	4 27
South	3 0 E	3 25 E	0 25	4 57 E	1 57	3 0 E	2 20 W	5 20
S. by W.	1 50 E	2 20 E	0 30	3 32 E	1 42	1 50 E	3 30 W	5 20
S.S.W.	0 25 W	0 10 E	0 15	2 17 E	1 52	0 25 W	4 40 W	4 15
S.W. by S.	1 50 W	1 2 W	0 48	0 12 E	1 38	1 50 W	5 50 W	4 0
S.W.	4 0 W	3 30 W	0 30	1 45 W	2 15	4 0 W	6 30 W	2 30
S.W. by W.	5 40 W	5 50 W	0 10	4 22 W	1 18	5 40 W	8 30 W	2 50
W.S.W.	7 52 W	7 15 W	0 37	6 22 W	1 30	7 52 W	9 0 W	1 8
W. by S.	9 37 W	9 22 W	0 15	9 7 W	0 30	9 37 W	9 40 W	0 3
West	11 24 W	11 0 W	0 24	11 25 W	0 1	11 24 W	11 20 W	0 4
W. by N.	12 37 W	12 0 W	0 37	13 0 W	0 23	12 37 W	11 45 W	0 52
W.N.W.	13 0 W	12 15 W	0 45	14 40 W	1 40	13 0 W	12 0 W	1 0
N.W. by W.	13 15 W	13 30 W	0 15	15 50 W	2 35	13 15 W	11 20 W	1 55
N.W.	12 45 W	12 12 W	0 33	15 15 W	2 30	12 45 W	10 35 W	2 10
N.W. by N.	11 25 W	11 0 W	0 25	14 2 W	2 37	11 25 W	9 40 W	1 45
N.N.W.	8 10 W	8 10 W	0 0	11 57 W	3 47	8 10 W	6 0 W	2 10
N. by W.	4 27 W	4 2 W	0 25	8 30 W	4 3	4 27 W	2 20 W	2 7

Since the Bloodhound was swung at Portsmouth in 1845, larger masts, with chain-rigging further aft, and an iron winch near the mainmast, have been placed on board, so that these results are not strictly comparable with those in Table IV.

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* This vessel had iron beams, and the elevation of the standard compass on the quarter-deck was 5¾ feet.

It will further appear by these results, that the differences of deviation under the two conditions, viz. when the fires are extinguished, and when they are lighted and the " steam up," are so small as, in all probability, to be rather attributable to circumstances incidental to compass observations on board ship, than to the effect of steam; and the same remark is applicable to the results which I obtained when the vessel was under way, and running in given directions with two land-marks in a line upon each course, the bearings of the said marks having been previously observed when the fires were extinguished, and the vessel's head steadily warped towards them. In these observations I was assisted by Lieut. Phillipps and Mr. Brunton.

Previously to the Bloodhound leaving the basin at Woolwich, in addition to a standard compass upon the quarter-deck, and another upon the forecastle, a dipping needle, Hansteen's magnetic intensity instrument, and a torsion instrument, were placed on board, and this with a view of ascertaining by means of the vertical and horizontal vibrations whether the magnetism of the vessel underwent any change in consequence of the fires being lighted and the " steam up;" before, however, the requisite observations could be completed, the water in the basin had ebbed three feet, thereby altering the relative position of the iron on the wharfs with respect to the instruments, and a large steam-vessel near to the Bloodhound having been removed for service during the observations, no comparisons of value could be established. I may remark, however, that the needle of the torsion instrument, which was only four and a half feet from the boilers, showed four degrees' difference of deflection when the boilers were in a heated state; but future experiments for determining minute effects in these particulars will probably be better tried in a vessel aground, and where the surrounding materials can remain in the same position during the experiments.

It may, I conceive, be worth the attention of persons concerned in the navigation of steam-vessels, and more particularly of iron-built vessels, in the Indian seas or other climates of a high temperature, to ascertain whether their magnetism be affected by the sun's rays, particularly in such cases as those where, by reason of the vessel's position or course, such rays are caused to impinge for any length of time more upon one side than the other.

It may also be desirable to ascertain what effect is produced upon the magnetism of an iron ship, when placed in the direction of the magnetic meridian for a few days, and again when secured at right angles to it for a similar period.

In conclusion, I have only to repeat, that the great diversity of facts which have come under my notice proves beyond all doubt the necessity which exists for the deviations of the compass being ascertained in all ships, not only at the extremes of their voyage, but at intermediate stations, and at sea, in the manner described in the "Practical Rules."

Binnacle Lamps.

It being of great importance to obtain good binnacle lights, which shall burn during a winter's night without smoke, or requiring trimming, the Lords Commissioners of the Admiralty have sanctioned the trial of several kinds, which hold out a fair prospect of accomplishing that desirable purpose.

OBSERVATIONS ON MAGNETISM.

The chief design of inserting a few general remarks on magnetism in this work, is to draw the attention of naval men to some of its peculiarities, and to the many excellent publications wherein every branch of the subject is treated of in detail.*

It is extremely difficult to ascertain with certainty the precise dates of remote discoveries, the periods of which are too often confounded with those when they have been adopted for practical purposes. To none more than the loadstone can this remark be strictly applied, — for centuries, probably, looked upon as a mere curiosity, or a mysterious agent used by the crafty to puzzle instead of guide.

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* In the "Encyclopædia Metropolitana," "Edinburgh Encyclopædia," and other works of this nature, the leading and most interesting facts relating to the phenomena of magnetism are clearly detailed; and also in many more concise works, such as "Cours de Physique de l'Ecole Polytechnique," par G. Lamé, tome deuxième; Barlow's "Essay on Magnetic Attractions;" Dr. Roget's "Treatise on Electricity, Galvanism, Magnetism, and Electro-Magnetism," in a volume of the "Library of Useful Knowledge." In the "Penny Cyclopædia" there is a good article on the subject; and in some of the old volumes of "l'Histoire de l'Académie des Sciences," and other French works, there are many descriptions of things relating to magnetism, which have at a later period been treated as modern discoveries.

Much information on magnetism may be gleaned from the works of M. de Humboldt, and in his last book, "Cosmos," translated under the superintendence of Lieut.-Colonel Sabine, there are many valuable remarks. An excellent paper on terrestrial magnetism, including a description of the methods recommended for observing the variation (*declination*), dip (*inclination*), and intensity, will be found in a "Report of the Committee of Physics of the Royal Society," 1840; and another small volume, "A Report on the *Isoclinal* and *Isodynamic* Lines in the British Islands, from the Observations of the Rev. Dr. Lloyd, Mr. Philips, Mr. Fox, Capt. Sir J. C. Ross, and Lieut.-Colonel Sabine," should not be overlooked.

Modern investigations, however, have placed magnetism in the list of sciences, and by the accumulation of well-authenticated facts, such as have been lately so sedulously sought out, by the simultaneous system of observations over the larger portion of the globe, we may yet hope to see it rank among the exact sciences, and that the future changes of these invisible magnetic currents may be as calculable as the more palpable tides of the ocean.

There is no doubt but the ancients were acquainted with the attractive power of the loadstone, although there is much uncertainty about the date of that invaluable discovery,—*its directive power*. A few quotations, however, will show the manner in which it is generally viewed:—

> "The term magnet is differently derived; some deduce it from Magnes, a shepherd, who is said to have discovered its attractive power by the iron of his crook, on Mount Ida; others assert that it was first discovered in Heraclea, a city of Magnesia, and that it hence derived its denomination, Magnet, as well as that of Lapis Heracleus, as it was sometimes called by ancient authors." "At all events, the Greeks called those ferruginous ores which possessed this power of attracting iron μάγνης, and from thence we derive our terms magnet and magnetism."
>
> "The discovery of the directive power of the magnet is by some assigned to a Neapolitan named Flavio, or John de Gioja, or Giova, or Gira, who lived in the thirteenth century."*

Dr. Gilbert, however, an English writer of the sixteenth century, affirms that Paulus Venetus brought the invention of the compass to Italy in the year 1260, having learned it of the Chinese; and on referring to the published letter of M. J. Klaproth to Baron Humboldt, "Sur l'Invention de la Boussole," there appears to be strong evidence to show that the Chinese were acquainted, not only with the properties of the magnet, but also with the use of the compass, long before it was known in Europe. After quoting the names which different nations have applied to the magnet, M. Klaproth observes, "Un fait très-remarquable est que presque toutes les dénominations de l'aimant en Europe se retrouvent aussi, quant à leur signification, dans les langues de l'Asie."

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* Encyclop. Metrop.

> "Duhalde, in his 'General History of China,' vol. i., in the annals of the Chinese monarchy, speaking of certain ambassadors, says, 'After they had their audience of leave, in order to return to their own country, *Tcheou Kong* gave them an instrument which on one side pointed towards the north, and on the opposite side towards the south, to direct them better on their way home than they had been directed in coming to China.' The instrument was called 'Tchi Nan,' which is the same name as the Chinese now give to the sea compass; and this circumstance has given occasion to think that Tcheou Kong was the inventor of the compass. This happened in the twenty-second cycle, more than 1040 years before Christ."

So little accurate knowledge as we have hitherto possessed of the Chinese, and so much as may be rationally expected from the present opening out of that great empire to European communications, their claims to the discovery will, probably, be either annulled or confirmed upon a more solid basis. We may safely say, however, Honour be to the memory of the discoverer, to whatever nation he belonged! for to the *directive power* of the *magnet* we are indebted more than to any other cause for our extensive knowledge of the globe we inhabit, and consequently for much of its civilisation. Honour be likewise to those names belonging to many nations which stand in the list of skilful navigators, not only of the olden time, but those of our own day, through whose courage and perseverance the whole human family have become acquainted! And not less honour be to those European philosophers who have been calmly and patiently investigating the laws by which the great physical truths belonging to our globe are governed!

Referring the reader to the notes at the foot of pages 121 and 124, for the titles of some of the works wherein detailed information on every branch of magnetism may be found, we shall proceed with that part which appears to bear more particularly on practical purposes, and in this place say a few words on the nature of the loadstone and the system of making artificial magnets.*

The *loadstone*, or *native magnet*, is an ore of iron, consisting chiefly of two oxides of that metal and a small proportion of quartz and alumina. It is found in considerable quantities in Norway and Sweden, also in Arabia and China; small loadstones have also been met with among the iron ores of England.

Artificial magnets, or such as those used for compass-needles, &c. &c., are made of bars of steel, having the magnetic property communicated either by drawing other magnets over their surface, or by the galvanic process, which is now known to produce most powerful magnets.

Among the methods for magnetising are those by "percussion," "juxtaposition," and the "single touch;" but that which is now most frequently adopted is the "double-touch" system, formerly introduced by Dr. Knight, and improved by Du Hamel Michel, Canton, Æpinus, Coulomb, &c.;† but it will be sufficient for our purpose in this place to mention that the results of the *single touch*, or that in which a magnet with one of its poles touching the centre of a steel bar, and drawn to its end, is to produce in the end last touched an opposite polarity to that possessed by the particular end of the magnet used; in other words, when the *north* pole of a magnet is last in contact with the end of the bar, south polarity is induced in that end and north polarity in the other, and *vice versâ* should the *south* pole of a magnet be used.

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* The various methods of making magnets, compass-needles, &c., which prevailed at different periods, are fully explained in the Encyclopædias already mentioned, and some additional information may be gleaned from Dr. Scoresby's "Magnetic Investigations."

With respect to the more difficult part of the subject—the theoretical discussion of its different branches—reference may be had to a variety of papers scattered through the publications of the learned societies of Europe, such as "Mémoires de l'Académie Royale des Sciences de l'Institut de France," "Annales de Chimie et de Physique," Edinburgh, Cambridge, and London "Philosophical Transactions," &c. &c.

A few of the papers in the latter may be here pointed to, especially those of Capt. Kater, Mr. Barlow, Mr. Christie, Dr. Lloyd, Mr. Harvey, Sir J. Lubbock, Mr. Airy, and the elaborate researches and reductions of magnetic observations over the greater part of the earth's surface by Lieut.-Colonel Sabine, together with his examination of the theories of M. Gauss, &c. &c.

† For a particular description of the different processes, see the "Encyclopædia Metropolitana," or the small volume by Dr. Roget, already alluded to also Dr. Scoresby's "Magnetic Investigations."

The method of magnetising by the "double touch" is to place the bar to be magnetised in a frame, having a piece of soft iron in contact with it at each end, and then to bring a couple of bar magnets (with their poles of opposite names nearest to each other) in contact with the centre of the bar, and draw them asunder along its surface to opposite ends, repeating the process eight or ten times over the entire surface, or till the bar shall have received the greatest magnetic power of which it is capable.

The method of induction for magnetising steel bars by the galvanic process, recommended by Dr. Faraday and practised by Mr. W. Jones, is to place the piece of steel to be magnetised between the ends of two soft iron cylinders which are enveloped by a helix of copper wire, but not in actual contact; the two cylinders serving the purpose of a pair of bar magnets, and communicating their magnetism by contact without friction when the battery is put in action.

Any galvanic battery will suffice. The copper wire proper to form the helix should be about one-sixth of an inch in thickness, the winding of the coil be in one direction, and the wire should be covered with tape to prevent any contact of copper and copper or of iron and copper. A hollow cylinder of pasteboard within the coil is the best security against the latter. The poles of the battery are to be connected in the usual manner to "make contact."

Some experiments indicate that an augmented magnetic power may be obtained by hammering and hardening the steel to a greater extent than is usual before magnetising it; and when the steel is very hard, I have found the electrical process produce an increase of power over the ordinary plan.

Experience has shown that hardness in the steel is an essential quality where retention of magnetism is desired; and, therefore, compass-needles should be made as hard as may be consistent with their practical application in other respects.

If a steel bar be heated to a red heat and placed near a magnet, it will be found on its removal from the magnet to have become magnetic; but heat will also destroy magnetism: for instance, if a compass-needle were heated to a white heat, its magnetism would be annihilated. It has also been ascertained that a change of temperature may affect the power of compass-needles.

The magnetism of compass-needles may be weakened or destroyed by rubbing poles of the same name together, or, by continuing the process, the poles may be changed; but if magnetic needles be placed with poles of opposite names nearest, and particularly if then connected by a piece of soft iron at each end, there is a tendency to preserve their magnetism.

The transmission of an electric discharge through a steel bar will induce magnetism; but it must also be observed, that such a discharge through a compass-needle already magnetised may not only weaken or destroy its magnetism, but also change its poles.

There is a curious circumstance on record in an old volume of the "Philosophical Transactions,"* where a ship's compasses had the poles of their needles changed by having been struck with lightning at sea.†

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* Vol. xiv. p. 520.

† 1851. Although the effect of electricity upon the compass has been so long known, we must not omit to record in this place a fact of recent occurrence upon our own shores.

A very marked effect of lightning upon the compass was observed on board

A piece of iron may be converted into a magnet by holding it in a vertical position (or more properly in the direction of the dip), and striking it several smart blows with a hammer, by which it acquires similar properties to those induced by the other processes, viz. attraction of unmagnetised iron, attraction and repulsion of magnetic iron, and the power of inducing magnetism in other iron. In this hemisphere, the end of the bar which points to the north being that which was lowest at the time it acquired its magnetism by hammering.

The variation of the intensities of magnetic attractions and repulsions exerted between any two poles has been found to depend upon their distances; or, in other words, "that the intensity of the force by which magnetic polarities act upon each other is inversely as the square of the distance."

In support, therefore, of that which has already been stated in a former part of this work, it is rendered yet more obvious, that all iron should be kept as far as may be practicable out of magnetic range of the compasses on board ship.

A bar of steel very carefully balanced before being magnetised, will, after that process has been performed in this hemisphere, on being delicately suspended, not only point to the magnetic north, but its north end will dip or assume an

H.M.S.V. Wildfire, Mr. Brockman, on her passage from Yarmouth to Sheerness, on July 10, 1851, when off Orfordness, J. Barlow, Esq., of H.M.S. London, being likewise on board.

The following is an extract from Mr. Brockman's report of the circumstance, transmitted by Vice-Admiral the Hon. Josceline Percy, C.B., to the Secretary of the Admiralty:—

"At 11h. 50m. A.M., I observed a flash of lightning from the W.S.W., having at its first appearance the form and colour of a small ball of fire, and terminating in a vivid angular line. The compass-card, when the lightning passed the ship, suddenly veered from S.W. (the course) to E.S.E., returned again, passing a little to the westward of the course, and then became steady in its proper position. At 11h. 58m. A.M. the card was again altered from S.W. to W.N.W. and continued westerly for about a minute. The last flash, similar in appearance to the first, came from a S. by W. direction."

inclination from the horizon in this latitude, at present about 68¾ degrees; while, if a similar process were resorted to at the magnetic equator, the bar would remain horizontal, both before and after magnetism had been communicated; and again, if a similar operation were performed in the south magnetic hemisphere, the *south* end of the needle would be found to dip.

Now it is evident, that as the dip increases, the directive power of the horizontal needle will decrease, and hence the local effect or deviation produced by the iron in the ship upon the compasses will be augmented; and here, again, is an additional reason for removing all such metal from their vicinity.

If either pole of a magnet be brought near any small piece of soft iron, it will be found to attract it. Iron filings are immediately collected when a magnet is placed among them, and when lifted hang in clusters near its poles; and if the *north* pole of a magnet be brought near the south pole of another magnet, it will attract it, but if the *north* pole of a magnet be brought near the *north* pole of another magnet, repulsion will be exhibited: in other words, poles of a similar name repel, and those of opposite names attract.

Now as there is no particle of magnetic iron, however small, which does not possess these properties, the object of repeating the preceding particulars, familiar as they may be to many, is to induce something more of their remembrance in the practice of navigation, and especially when placing an instrument of such vital importance as the compass on board ship.*

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* As it has been proved that the rate of a chronometer is altered by its proximity to an iron body (see "Phil. Trans." 1820), care should, therefore, be taken in placing these instruments at a distance from such metal; and in iron ships precautions in this respect are eminently requisite. Perhaps the centre line of the ship, as far from any masses of iron (and equidistant from them) as may be practicable, will be found the most eligible, regard being had to placing the balance in such a position, with respect to the magnetism of the ship, as it may be most equally affected by it.

Mr. Barlow ascertained the proportional magnetic powers of different kinds of iron to be as follows :—

Malleable iron	100
Cast iron	48
Blistered steel (soft)	67
Ditto (hard)	53
Shear steel (soft)	66
Ditto (hard)	53
Cast steel (soft)	74
Ditto (hard)	49

In addition to that which has been said in the paragraph following the "Practical Rules," respecting the diminution of deviation as we recede from the magnetic poles, it being *nil* at the magnetic equator, and changing signs of + and − (or W. and E.) on the ship passing from one magnetic hemisphere to the other, and also from recent observations, that it appeared a portion of time was necessary for a ship to acquire a change in her magnetic properties, after passing the line of no dip, it will be evident from the preceding remarks on the different properties of iron, &c., that it is safer to rely upon actual observation than theory in this respect, more particularly when it is considered that it is possible for some of the iron in the vicinity of the compasses to approximate to the character of permanent magnets, while other portions do not maintain that character, nor yet altogether that of soft iron, in which magnetism would be induced according to the ship's position : so that all these circumstances inculcate the necessity of constant observation in each ship.

There are other metallic substances besides iron which are capable of exhibiting magnetic effects, as, for instance, nickel* and some other metals in a less degree ; and of the mixed metals, impure brass frequently shows magnetic properties : hence the necessity of examining the tops of binnacles, lamps, &c., to ascertain if they are free from magnetism. Besides the fact that a number of the minerals exhibit an effect upon the magnetic needle, it may be observed that many other bodies, when brought very near, exert a feeble influence over it.*

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* Biot, "Traité de Physique," tom. iii.

Numerous experiments have proved that there is no substance yet known which has the power of intercepting the action of magnets upon each other.

The magnetism of rotation was shown by M. Arago in 1824. A plate of copper, placed immediately below a magnetic needle, was found to diminish sensibly the extent of its oscillations; and when a plate of copper is made to revolve with a certain velocity under a magnetic needle, supported on its centre and closed in on all sides, the needle is found to deviate from its natural position in the magnetic meridian.

Professors Christie and Barlow made many interesting experiments on the revolutions of an iron plate (see "Phil. Trans." 1825), and the investigation of the subject was continued by Mr. Babbage and Sir John Herschel, who showed that the rapid revolution of a disc of copper, zinc, or lead, would cause a magnetic needle to deviate from the magnetic meridian; and reversing the experiment, by setting a horse-shoe magnet with its poles uppermost in quick rotation, the disc was found to follow the motion of the magnet.

Many other experiments were tried which threw much light upon the subject, the results of which are described in the volume of the "Phil. Trans." above alluded to; and these were again followed up by Sir W. Snow Harris, whose account of the results he obtained may be seen in the "Phil. Trans." of 1830. The effect of various metals in diminishing the oscillations of the magnetic needle was also ascertained to a considerable extent by Professor Seebeck. See "Annales de Physique," 1826.†

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* Coulomb, 1802.

† 1850. In a small but interesting volume, entitled "Rudimentary Magnetism," by Sir W. Snow Harris, F.R.S., the effect of the copper ring in reducing the oscillations of the magnetic needle is described, and also various

Electro-Magnetism.

It is stated, "that while Æpinus was intent upon improving the electrical theory of Franklin, he was struck with the remarkable similarity in the attractions and repulsions exhibited by the tourmaline when heated, to those of magnetic bodies; and it occurred to him that the phenomena of magnetism might be derived from the agency of a peculiar fluid, having properties very similar to those of the electric fluid, but which acted exclusively upon iron." For the discussions, however, of the propositions of Æpinus, the reader is referred to the works already named, as their insertion here would far exceed the prescribed limits of this book; but the extraordinary advance in the knowledge of electricity in connexion with magnetism, which has been made since the time of that philosopher, may not be passed over without some comment; and, therefore, having before adverted to the effects which electricity produces upon steel bars and magnetic needles, a few words on electro-magnetism may possibly prove a useful adjunct.

Although at an earlier period it was suspected that a strong analogy existed between the electric and magnetic fluids, and it was known so far back as 1750 that the aurora borealis affected the compass needle, yet it was not until recourse was had to the galvanic battery, which was ascertained to possess electrical properties, that their intimate relation became so apparent.

The experiments of Ritter and Professor Oersted of Copenhagen seemed to indicate an analogy between the electric, galvanic, and magnetic fluids; and the latter, in the year 1820, completely succeeded in establishing the

methods of magnetising steel bars, together with observations on the diamagnetic condition of metals, magneto-electricity, &c. &c.; and this little work is rendered the more useful by numerous plates illustrating each branch of the subject.

reciprocal action of the galvanic and magnetic fluids upon each other by the most conclusive experiments, which have since then been much extended by Ampere, Biot, and Arago in France; by Sir H. Davy, Professor Cummings, and Dr. Faraday in England; and by several philosophers in Germany.

The effect of the uniting wire passing to the needle through glass, metals, wood, water, resin, stoneware, stones, &c., was clearly developed; also that two galvanic wires acted upon each other, and that such wires had likewise an action upon iron filings, and would hold them suspended like an artificial magnet.

Both Sir H. Davy and M. Arago succeeded in magnetising steel wires by the galvanic battery, and M. Ampere showed the direction which a freely-suspended galvanic wire would assume under the action of terrestrial magnetism; while Faraday developed the tendency of the magnetic needle to revolve about the wire, and Ampere actually succeeded in causing the magnet to revolve on its own axis, by introducing it as a part of the galvanic circuit.*

Mr. Barlow having reduced the laws of induced magnetism to mathematical principles, so far as to render the results susceptible of numerical computation, the mass of iron and its position being given, he then proceeded in his endeavours to establish on similar principles the law of electro-magnetism; but it would be impossible to do justice to these investigations in a sketch of this nature, and, therefore, reference should be had to his own and the other publications named a few pages back, for a full explanation of the experiments and the results to which they led. We cannot refrain, however, from mentioning the ingenious manner in which the effect of terrestrial magnetism was approximately imitated (at least so far as the dip observations then extended), by distributing wires round the surface of an artificial globe, and then directing a galvanic current through them.

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* For the particular effect produced on each pole, according to the position in which the electricity is made to enter, and for various other results obtained by MM. Ampere, Faraday, and Davy, see Barlow's "Sketch of Electro-Magnetism."

> "Mr. Barlow, having procured a hollow wooden globe, 16 inches in diameter, furnished it with copper wires passing in grooves along each parallel of latitude for every tenth degree. When an electrical current was made to pass through these wires in the same direction in each, it was found that a magnetic needle, properly neutralised with regard to the earth's action, and suspended in different situations near the surface of the artificial globe, arranged itself in positions analogous to those actually assumed by the dipping-needle in corresponding regions of the earth."*

It is necessary to remark, however, that more recent and extensive researches show that, to imitate exactly all the peculiarities of terrestrial magnetism, with its various curves, its poles of verticity and intensity, &c., greater difficulties exist than have yet been surmounted by miniature experiments; † and although it is now well known that magnetism can be induced by electricity, and electricity by magnetism, the former giving the peculiar character of polarity to steel, and the latter producing sparks of the most intense and beautiful light, yet there are anomalies still to be cleared up before they can be pronounced identical.

The extensive and valuable researches of our distinguished countryman, Dr. Faraday, crowned by his last brilliant discovery that the oxygen of the air is magnetic, will be read with the deepest interest by all who desire accurate information on the subject.

With respect to the causes which have been assigned for the production of magnetism, and particularly as to whether the electrical currents in or about the crust of the earth are attributable to the solar rays, most of that which is known on the subject will be found in the works already mentioned; but, in conclusion, it may be briefly stated that there are strong grounds for the belief that there exists an intimate relation between heat, light, electricity, and magnetism.*

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* Dr. Roget's "Treatise."

† 1850. Vide a work entitled "Scientific Researches, Experimental and Theoretical, in Electricity, Magnetism, Galvanism, Electro-Magnetism, and Electro-Chemistry." By William Sturgeon, Lecturer on Natural and Experimental Philosophy.

Theories of Magnetism.

Of the different theories of magnetism which were attempted for a protracted series of years, it has been said, and with much truth, that they deserve little better than the appellation of vague notions. But, to pass on from these to investigations of a different character,—"Dr. Gilbert [1600] appears to have been the first to attempt any hypothesis with a view of reducing the laws of magnetic action to something like a theoretical form; but there were too few facts then known to enable him to approach to a correct theory;" and the last remark may be justly applied to the attempts of several other philosophers who followed him: indeed, from what we now know of the movements of this invisible and mysterious element, or action of the magnetic fluid, in or about the crust of the earth, the effects of that action being manifested by magnetised bars or needles, it does not appear surprising that so long a period of time should have elapsed before such a collection of facts could be obtained, more particularly when we consider that during the earlier periods the chief element referred to was the *variation* only.

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* See, in the volumes alluded to, an account of the experiments, &c. of Professors Seebeck and Cumming, Morrichini, Christie, Nobili, Mollini, Mrs. Somerville, Casini, Radolfi, Sir H. Davy, Col. Gibbs, M. Cuvier, Sir D. Brewster, Faraday, Oersted, Dr. Wollaston, Van Beck, Van Rees, Noele, De la Rive, Kater, Barlow, &c. &c. on the several subjects of heat, light, electricity, and magnetism; and we may also refer to a pamphlet by Mr. Grove, "On the Correlation of Physical Forces," which has been recently published.

In the year 1683, Dr. Edmund Halley published a theory of magnetism; and a few years afterwards, having undertaken a voyage for the purpose of observation, he constructed a magnetic chart; and since that period some others have appeared, among which may be mentioned those in Hansteen's Magnetic Atlas, the useful work of Mr. Barlow, and that of M. Adolf Erman, after his journey in company with Hansteen and Due; and although it is now clearly understood that both the dip and intensity are elements requisite to be known, yet these productions pointed out that other investigations were necessary to the right understanding of the subject.

It is but just to notice, in this place, that notwithstanding the apparent irregularities which the *variation* presented in different parts of the world, Halley drew the conclusion that they were due to forces which must produce two points of greatest attraction in each hemisphere.*

Before proceeding further with these general remarks, it may be necessary to premise that it was not till many philosophers had attempted to discover the cause, and to develope the laws of the action of magnets upon each other, that any very satisfactory progress was made.

Dr. Knight's system of making artificial magnets, improved by Du Hamel, Michel, and Canton, served as a foundation for future experiments to clear up the difficulties which presented themselves at the outset of the inquiry; and after the investigations of Muschenbrook, Mayer, and Lambert, Coulomb in 1786 (aided by the balance of torsion) succeeded in establishing, on more satisfactory grounds, that the law of attraction and repulsion existing between two magnetic particles is always "inversely as the square of the distance." This result was further verified by Professor Hansteen; and it may be added, in this place, that the later investigations of Mr. Barlow and other scientific men of our own time have done much to clear away the mists in which this difficult subject has been for ages enveloped. But to return to the different theories. The hypothesis of two magnetic fluids (austral and boreal) was first propounded by Wilke and Brugman; but the physical principles on which the theory rests were developed by Coulomb, and have of late years been most elaborately discussed by M. Poisson, who assumes that the magnetic force of the globe varies in different parts of it, both in direction and intensity, and depends on the distribution of two magnetic fluids in its mass, with which we are unacquainted, the intensity and direction at a given point being determinable by experiment.

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* It may here be observed that Hansteen, in combining these with the magnetic force, considered that there were four points of convergence among the variations.

M. Biot assumed that there was an infinitely small magnet at the centre of the earth, and investigated formulæ according to this hypothesis;* while M. Hansteen assumed the existence of two magnets of unequal strength at certain distances from the centre of the earth; and Professor Gauss, in his "Treatise on the General Theory of Terrestrial Magnetism," assumes that the terrestrial force is the collective action of all the magnetised particles in the earth's mass.

It may here be observed, that the elaborate formulæ of some of these learned and ingenious authors represented in many places certain magnetic phenomena, which have been since actually observed there; but that none of them have as yet fulfilled all the conditions which our present enlarged collection of magnetic observations demands, extending as they now do over so large a portion of the globe.

In adverting to this collection of observations,† those of

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* See also Professor Kraft's investigations of a much earlier date.

† The examination of the magnetic intensity is stated to have commenced with the unfortunate and lamented La Pérouse, at the instance of l'Académie des Sciences.

Humboldt in South America, France, Italy, and Germany—of Hansteen, Due, and Erman in the north of Europe and in Siberia—of Lieut.-Colonel Sabine, in the Polar Seas and equatorial regions of Africa and America—of the Russian Admiral Lütke, in a circumnavigation of the globe—of Captains King and Fitzroy in South America—of Beechy and Belcher in the Pacific—of Parry, Ross, Franklin, and Back in the northern hemisphere—and of Lamanon, De Rossel, Duperrey, and Krusenstern in the southern, should be remembered with respect; nor should the earlier records of Byron, Cook, Halley, and Vancouver, be overlooked, forerunners as they were, although in a less perfect way, of that admirable system of simultaneous observations which has since been arranged and worked out in the four quarters of the globe, and which are rendered still more valuable by their appropriate accompaniment, the results obtained by Sir James Clark Ross during the antarctic expedition.

The elements measured by this system of simultaneous observations were,—

1st. The varying *intensity* of the terrestrial force;
2d. The varying *inclination*, or dip, of the magnetic needle; and
3d. The varying *declination*, or variation, of the magnetic needle from the geographical meridian.

The aggregate effect of these three divisions of the subject has been beautifully represented by Lieut.-Colonel Sabine in several maps, containing three systems of curved lines denominated *isodynamic*, or lines of equal force; *isoclinal*, or lines of equal dip; and *isogonic*, or lines of equal variation.

The *isogonal* lines, or lines of equal variation, are by no means parallel to each other, but present a great variety of flexures; a part of them appear to converge towards two points on the earth's surface, one in or near Baffin's Bay, and the other to the southward of New Holland.*

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* "Professor Hansteen has deduced from the observations which have been made in the polar regions, that the *isogonal* lines in the northern hemi-

The *isoclinal* lines, or lines of equal dip, seem to represent irregular ovals, but these ovals go on diminishing in magnitude in each hemisphere towards the poles of greatest dip.

The dip of 90° was observed in the northern hemisphere by Sir James Clark Ross in 1831, in latitude about 70° N. and longitude 117° W. The greatest dip yet observed in the southern hemisphere was also by Sir James Ross, in latitude 76° S. and longitude 165° E. It was 88° 35′. The geographical position (were it accessible) in which the dipping needle would be found to rest in a vertical position with the south pole downwards may probably be about 74° S. and 150° E.

The *isodynamic* lines, or lines of equal intensity, appear to be of an oval form, and constitute a system with loops, or with two polar points, in the northern hemisphere; the western pole of maximum intensity has been ascertained to be in latitude 52° N. and longitude about 90° W., near Hudson's Bay, while the eastern or Siberian pole (the weaker of the two) is about the latitude of 70° N. and longitude 120° E.

In the southern hemisphere the curves, as they are more distant from the equator, assume more perceptibly the form of loops about two points or poles, which, by rough estimation, may be in latitude 60° and longitude 140°, that is, to the south of New Holland; and the other about the same high latitude, and in longitude 120 W., or in the south part of the Pacific Ocean.

It may be proper to remark, that there appears to be one pole of stronger and one of weaker intensity in each of the terrestrial hemispheres; but until all the necessary observations shall have been collected and reduced for marking

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sphere tend to two points in the vicinity of the pole of the dip; those which are on the north side uniting in a point a little way to the north of the latter pole, and those on the south side a little way to the south of the same pole."—*Cosmos.*

accurately and distinctly the character and movements of the magnetic elements (and they are fast progressing in the unwearied and able hands of Lieut.-Colonel Sabine), further observations, perhaps, might be considered premature in a work of this kind.

We may observe, however, that from the improved nature of the instruments with which the observations were made (for a description of which the published papers of M. Gauss and some other of the German philosophers, and likewise those of the Rev. Dr. Lloyd, may be referred to), and the skill of the observers who have so accurately and extensively measured the earth's magnetism, little doubt can be entertained but that ultimately a correct theory will be deduced; although, from the observations which accompany these maps, it would appear that each branch of a curve has its own history, and hence additional complexity in arriving at a formula which shall represent so many peculiarities.

One of the most marked results of the system of simultaneous observations was the discovery, that unusually great disturbances of the magnetic needle take place over a large portion of the earth's surface at the same time.

A disturbance of this nature was observed on the 25th and 26th of September, 1841, at the following places:—Greenwich, Siberia, all over Europe; in North America; in Vandieman Island; at the Cape of Good Hope and St. Helena; at Simla in the Himalaya; and at Macao in China.

By the judicious system adopted, and the wide range of magnetic observations over earth and ocean, the important fact that the poles of verticity, or points of greatest dip, are not coincident with those of greatest intensity, has been fully established; and this circumstance, combined with the peculiar features of the magnetic curves and the line of no dip, sufficiently show the necessity for a revision of the theory of terrestrial magnetism.

There is one feature relating to the magnetic observations from which these maps have been drawn that deserves particular notice, and that is the large space of *ocean* over which they have been extended. Formerly it was considered impossible to make accurate observations upon the dip on board ship; but now, from modern ingenuity, it may be reasonably doubted whether the ship observations do not measure the phenomena more accurately than those upon land, inasmuch as the amount of the ship's local influence on the needle can be ascertained, while that of any peculiar district on land remains uncertain.*

It would appear, that at particular parts of the earth's surface (for example, in the western part of the Antilles and in Spitzbergen), the mean *variation* (or declination) of the magnetic needle has scarcely undergone any material change in the course of the last hundred years;† while in other places, or over the greatest part of the globe, the contrary is the fact, the changes being very marked.

Although it must be remembered, that at the earlier periods of magnetic observations no such refinements in the construction and use of instruments as those now adopted for the purpose of accuracy were employed, neither was the local attraction of ships taken into account, and that no observations were then made upon the magnetic intensity or force; yet a short table, showing the change which has taken place in the two first elements (*variation* and *dip*), observed in London and a few other places, may prove useful, and is therefore inserted.

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* See observations of Sir James C. Ross and Capt. Crozier during the antarctic expedition.

† See Humboldt's "Cosmos," translated under the superintendence of Lieut.-Colonel Sabine.

TABLE XIV.

LONDON, and its Vicinity.				PARIS.				PETERSBURG.				ST. HELENA.				OTAHEITE.			
Date.	Variation.	Dip.	Date.	Date.	Variation.	Dip.	Date.	Date.	Variation.	Dip.	Date.	Date.	Variation.	Dip.	Date.	Date.	Variation.	Dip.	Date.
						° ′			° ′	° ′			° ′	° ′			° ′	° ′	
1580	11° 15′ E	71° 50′ N	1576	1580	11° 30′ E														
1622	5 56 E	72 30 N	1613									1623	6 0 E						
1634	4 5 E			1630	4 30 E														
1657	0 0			1660	1 0 E														
				1666	0 0														
1672	2 30 W	73 30 N	1676	1670	1 30 W	75 0 N	1671					1677	0 40 E						
												1691	1 0 W						
1723	14 17 W	74 42 N	1723	1723	13 0 W			1726	3 15 W			1724	7 30 W						
1745	17 0 W			1750	17 15 W	72 15 N	1754							9 0 S	1754	1765	5 0 E	30 43 S	1769
1773	21 9 W	72 19 N	1772	1773	20 0 W	72 25 N	1776	1773	4 50 W	73 30 N	1755	1775	12 18 W	11 25 S	1775	1777	5 34 E	29 59 S	1774
1786	23 17 W	72 8 N						1784	8 13 W	72 36 N	1778	1789	15 30 W						
1790	23 39 W	71 53 N	1790	1790	21 0 W	70 52 N	1791									1792	6 12 E		
1804	24 8 W	70 25 N	1805	1804	22 5 W	69 12 N		1806	7 52 W			1806	17 18 W						
1813	24 22 W			1814	22 34 W	68 36 N		1812	7 16 W										
1815	24 27 W																		
1820	24 11 W			1819	22 29 W	68 40 N	1817	1818	7 27 W							1823	6 40 E	30 3 S	1823
1821		70 4 N	1821	1824	22 23 W	68 9 N	1823									1826	7 23 E	30 29½ S	1830
1828		69 47 N	1828	1829	22 12 W	67 58 N	1827	1828	6 41 W	71 8 N	1828	1836	18 0 W	18 15 S	1836	1836	7 34 E	30 13½ S	1835
1838	23 59 W	69 17 N	1838	1835	22 4 W	67 13 N	1838	1842	6 21 W	71 0 N	1842	1840		18 16 S	1840	1840	6 30 E		
1846	22 49 W	68 50 N	1846									1846	*	19 23 S	1846				
1849	22 35 W		1849	1849	20 0 W		1849	1849	5 50 W	70 5 N	1849	1849	23 5 W	22 39 S	1849				
1850	22 24 W	68 47 N	1850																

* In volcanic countries, such as St. Helena, the amount of dip and variation is found to be materially affected according to the locality of the instrument.

I am indebted to the Astronomer Royal for the mean variation at Greenwich for 1846 and 1850, and also for the Table containing the monthly changes observed at the Royal Observatory, Greenwich, inserted in p. 146; to Sir James C. Ross for that observed at Bushy, 1838; and to Lieut.-Colonel Sabine for the dip observed in and near London for four preceding periods, the observations having been made at the following localities: 1st, Regent's Park; 2d, Horticultural Gardens, Chiswick; 3d, Westbourne Green; 4th, near Woolwich; and the results for 1849 were obligingly sent to me by Capt. Younghusband, R.A.

The other authorities quoted for the *variation* in London are Burroughs, Gunter, Gillebrand, Bond, Halley, Graham, Heberden, Gilpin, Beaufoy; and those for the *dip*, Norman, Ridley, Bond, Graham, Nairne, and Gilpin.

In Paris, the authorities quoted are Sennertus, Petit, Picard, Maraldi, Cassini, Le Monnier, Cotte, Bouvard, Arago; and those for the dip, Richer, La Caille, Le Monnier, Cassini, Fox, and Arago.

In Petersburg, Mayer, Euler, Henry, Wisnienski, Kupffer, and Erman; at St. Helena, Davis, Halley, La Caille, Cook, Hunter, Krusenstern, King, Fitzroy, and Ross; and at Otaheite, Byron, Cook, Vancouver, Duperrey, Fitzroy, and Belcher.

In addition to the labours of Colonel Sabine in the reduction of magnetic observations over so large a portion of the globe, we are indebted to him for tables of the variation in the Atlantic, between the latitudes of 60° north and 60° south (see "Phil. Trans." already noticed in this work); and that which renders this table yet more valuable is, that it is computed to a given epoch (1840), and is accompanied by another table showing the annual secular changes of variation on the average of fifty-three years antecedent to that period.

The variation is stated by Burroughs to have been 11° 15′ East at Limehouse, in 1580; and it will be seen by the preceding table that in London and its vicinity the compass-needle pointed to the *true* north in 1660, or, in other words, there was no variation: and from that period the westerly variation *increased* till 1819, since which it has *decreased* up to the present time.*

According to Colonel Beaufoy, who was known to be a most accurate observer, the magnetic needle attained its greatest westerly variation in the month of March 1819, as shown by the following quotation from the "Quarterly Journal of Science," 1820:—

> "During the last nine months of 1818, the variation gradually increased, and was in the morning 24° 37′ 4″, and at noon 24° 41′ 20″. It fluctuated during January 1819, decreased in February, and again fluctuated in March. Since that time, the mean monthly variation has decreased continually; and Colonel Beaufoy, therefore, places the maximum of western variation (*declination*) about the month of March, 1819."

In addition to the secular changes of variation, or of the mean annual horizontal motion of the needle, there are daily and hourly, or, to speak more accurately, *perpetual* changes in the variation going on, and the same as respects the dip and intensity. Small, indeed, as these changes are when spread over an hour, a day, or year, yet they are equally certain as larger quantities, and essential to be known before the true law which regulates this subtle phenomenon can be discovered.

> "In the northern hemisphere, the mean movement of the north end of the needle, from 8½ A.M. to 1½ P.M., is from east to west; and at the same hours in the southern hemisphere, the same end of the needle moves in an opposite direction, or from west to east."

With respect to the intensity of the magnetic force, I cannot forbear quoting the following from the notes appended to the work already alluded to, "Cosmos," by Baron von Humboldt:—

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* In the Greenwich Observations, in the annual means, I have observed one exception to this.

> "I observed the same needle perform in ten minutes, at Paris, 245 oscillations; at Havanna, 246; at Mexico, 242; at San Carlos del Rio Negro (lat. 1° 53′ N., long. 80° 40′ W. from Paris), 216; on the magnetic equator or line, where the inclination = 0, in Peru (in 7° 1′ S. lat., and 80° 40′ W. long. from Paris), only 211; and in Lima (12° 2′ S. lat.), again 219 oscillations."—Vol. i. p. 416.
>
> "The greatest intensity of the magnetic force hitherto observed on the surface of the earth is 2·071, and the least 0·706.* Both are in the southern hemisphere. The geographical position of the first is lat. 60° 19′ S., long. 131° 20′ E. from Greenwich, observed by Sir James Ross where the inclination was 83° 31′. (Sabine, Contributions to Terrestrial Magnetism. No. V. 'Philosophical Transactions,' 1843, p. 231.) The minimum was observed by Erman in 20° 0′ S., and 324° 57′ E. from Greenwich (Erman, 'Phys. Beob.' 1841, s. 570), at which point the inclination was 7° 56′. These values of the force are in the ratio to each other of 1 to 2·933. It was long supposed that the ratio of the greatest to the least intensity of the force on the surface of the earth was 2 to 1. (Sabine, 'Report on Magnetic Intensity,' p. 82.)"
>
> "On Melville Island (lat. 74° 27′ N.), in the neighbourhood of the north magnetic pole, the force was found by Sabine to be only 1·624, while at New York, U.S. he found it to be 1·803."

Of the ever-varying effects of magnetism upon the movements of the needle, no better proof can be desired than that to be found in the tables, maps, and diagrams, already referred to; but, perhaps, it may be useful in a work of this nature to insert a table showing the extent of the diurnal variation in this latitude, as being more immediately connected with practical purposes, and the following extract from the Greenwich Observations of 1842 will fully answer that design:—

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* These intensities are expressed in terms of the scale of which the unit is the intensity which Humboldt observed in the north of Peru.

TABLE XV.

Mean Westerly Declination (Variation) of the Magnet at every even Hour of Göttingen Mean Time, deduced from all the Observations taken at that Hour in each Month.

1842.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
Göttingen Mean Time.	23°	23°	23°	23°	23°	23°	23°	23°	23°	23°	23°	23°
Hour. 14	12′ 3″	11′ 57″	8′ 11″	8′ 2″	9′ 32″	12′ 28″	13′ 55″	13′ 19″	11′ 26″	16′ 18″	16′ 18″	16′ 23″
16	11 39	13 2	8 11	8 39	9 31	12 11	13 26	12 6	11 51	16 41	16 43	16 53
18	12 2	13 36	8 43	10 11	7 55	11 48	15 59	12 9	12 21	16 36	16 46	16 38
20	11 54	15 0	8 13	8 49	6 47	10 43	13 12	11 45	13 2	16 13	17 7	17 21
22	12 58	15 50	11 37	11 17	10 12	12 29	16 33	15 17	15 52	17 27	17 55	17 58
0	14 52	18 40	14 54	14 36	16 8	16 43	21 17	20 22	20 23	22 23	20 45	20 22
2	15 19	20 46	16 41	17 52	18 3	19 47	24 11	22 7	20 56	24 5	21 35	20 36
4	12 51	19 25	14 33	15 16	15 50	18 53	22 23	19 12	16 55	21 37	18 46	18 47
6	11 55	17 0	11 43	12 16	12 18	15 55	19 45	15 49	13 49	18 34	17 35	16 55
8	10 16	14 34	10 6	9 25	12 16	13 28	17 26	14 21	11 14	16 37	16 19	15 53
10	8 4	13 31	6 35	8 19	11 17	12 51	14 23	12 53	11 42	14 30	14 30	15 5
12	8 51	11 15	7 38	7 20	10 0	10 54	14 21	12 42	10 44	15 42	15 4	15 30

The difference of time between Göttingen and Greenwich is 39′ 46″.

"The westerly declination is, without exception, greater at 2 than at any other hour; the excess in the winter months over that at 0 hour is very small, particularly in December. Starting from the 2 hour the movement is continuous towards the east until 8^h, 10^h, or 12^h, when the magnet returns towards the west and reaches a second westerly limit; then a second movement towards the east takes place, which limit is generally attained late in the morning: from this time the return is continuous towards the west."

The following results, with which the Astronomer Royal has kindly favoured me, show the monthly changes of variation (magnetic declination) at the Royal Observatory, Greenwich for 1850, the mean variation for that year being 22° 24′ W., and the dip 68° 47′ N.

TABLE XVI.

1850.	January	22° 28′ W.	1850.	July	22° 24′ W.
	February	22 28 W.		August	22 23 W.
	March	22 27 W.		September	22 26 W.
	April	22 26 W.		October	22 20 W.
	May	22 27 W.		November	22 19 W.
	June	22 25 W.		December	22 19 W.

The preceding quotations and remarks, it is hoped, have been sufficiently multiplied to have the desired effect of drawing the attention of naval men to the works in which the different branches of magnetism are explained in detail; and it is now proposed to conclude this sketch with a table showing the periods at which some of the properties and movements of the magnetic needle were discovered, together with the names of the individuals to whom the honour of such discovery is usually assigned; by which table it will be seen how slowly facts of importance on this subject have been established: a truth which cannot be more forcibly marked than by the circumstance, that a century appears to have elapsed after the compass was known before its variation was observed, and more than two centuries from that period passed away before it was ascertained that the variation was not the same in all places,—a discovery due to the great Columbus himself.

If we assume that the use of the compass was known in Europe in the latter part of the eleventh or beginning of the twelfth century, the following table will exhibit in approximate chronological order some of the earlier and more prominent discoveries respecting it; the observations of late years, together with remarks thereon, being inserted under their respective heads in different parts of this work.

Date.	Phenomena.	Name of Observer.
1269	Variation of the compass............	Peter Adsiger.
1492	Variation not the same in all places ..	Columbus.
1576	Dip of the magnetic needle..........	Robert Norman.
1633	Variation not the same at the same place in successive years	T. Mair. Mr. Gunter. Professor Gillebrand.
1684	Effect of a ship's iron upon the compass	Capt. S. Sturmy.
1722	Diurnal variation..................	Mr. Graham.
1750	Compass affected by the aurora borealis	Professor Wargentin.
1786	Balance of torsion. Attraction and repulsion of magnetic particles "inversely as the square of the distance"	Coulomb.
1820	Investigation of certain laws respecting iron bodies, and the application of an iron plate to correct a compass for a ship's local attraction	Mr. Barlow.
1820	Reciprocal action of galvanism and magnetism fully established	Professor Oersted.
1824	Magnetism of rotation, and the proximity of metals reducing the oscillations of the magnetic needle......	Arago.

The observations of Captain Kellett, C.B., during his late arduous voyage, show a change of deviation according to the change of the ship's geographical position, and in some places, where the shore-instrument was placed on or near volcanic rocks, confirm the remarks that have been made on that subject at paragraph 10 of the "Practical Rules," showing that it is not safe to rely on results obtained on or near the shore in volcanic countries.

The return of the expedition under Captain Austin, C.B., from his extensive search in the Arctic regions, enables me to insert a table of the deviations of H.M.S. Resolute, which denotes the great change of deviation in high northern latitudes.

This table must be considered supplementary to Tables IX., X., and XI., and is entirely confirmatory of the remarks on that branch of the subject, printed in the first and repeated in the second edition of this work.

	Dip 68¾ N.	Dip 82·11 N.
Direction of Ship's Head by Standard Compass.	Deviation of Standard Compass. — Greenhithe, 1850.	Deviation of Standard Compass. — Whale Fish Islands, 1850.
North	1° 35′ E	3° 0′ E
N. by E.	2 45 E	5 55 E
N.N.E.	3 55 E	9 10 E
N.E. by N.	5 2 E	16 0 E
N.E.	6 10 E	16 20 E
N.E. by E.	6 20 E	17 30 E
E.N.E.	6 30 E	17 50 E
E. by N.	6 35 E	17 50 E
East	6 30 E	17 0 E
E. by S.	6 0 E	17 0 E
E.S.E.	5 42 E	15 5 E
S.E. by E.	3 50 E	12 45 E
S.E.	2 0 E	10 40 E
S.E. by S.	1 10 E	9 10 E
S.S.E.	0 55 E	5 40 E
S. by E.	0 10 E	2 20 E
South	1 40 W	0 50 W
S. by W.	2 55 W	5 10 W
S.S.W.	4 10 W	6 50 W
S.W. by S.	4 50 W	10 30 W
S.W.	5 30 W	11 10 W
S.W. by W.	5 50 W	15 0 W
W.S.W.	6 10 W	15 30 W
W. by S.	6 35 W	17 58 W
West	6 15 W	
W. by N.	6 10 W	
W.N.W.	6 5 W	14 20 W
N.W. by W.	5 15 W	13 40 W
N.W.	4 25 W	10 30 W
N.W. by N.	2 10 W	8 10 W
N.N.W.	1 0 W	6 40 W
N. by W.	0 13 W	1 5 W
Observers,	Capt. Johnson	Mr. R. C. Allen.

ADDITIONAL NOTES

ON THE

LOCAL ATTRACTION OF SHIPS.

The attraction which the iron in ships exerts upon the magnetic needle, and the consequent divergence in their course, were noticed upwards of 160 years ago. See the copy of Captain Samuel Sturmy's "Mariner's Magazine" of 1684, in the British Museum, and referred to by a writer in the "Nautical Magazine."

In 1691-1693, Dampier noticed and recorded the great irregularities in compass observations.

In 1776-1780, Mr. Wales, astronomer with Captain Cook, remarked differences even to the amount of 10° in the variations obtained when the observations were made with the ship's head in different positions.

Mr. Downie, in 1790, observed that the compass would not always point in the same direction when placed in different parts of a ship, and that two ships steering the same course by their respective compasses would not go exactly parallel to each other. He also considered this to be the effect of the quantity and vicinity of the iron in most ships.

M. Beautemps Beaupré [1793], when searching for La Peyrouse, abandoned the old system of compass bearings, in consequence of meeting with differences of several degrees in the *variations.*

In 1801, Captain Flinders, of his majesty's ship Investigator, clearly proved, by a series of azimuths taken by the same compasses in different parts of the ship, that a change of place of the compass from the binnacle to a little before the centre of the ship, produced an alteration of 4° 37′ in the mean variation (see vol. i. page 17, of his "Voyage to Terra Australis"); and on his return from the survey of Australia, in 1810, the Lords Commissioners of the Admiralty directed him to make a series of experiments on board one of his majesty's ships at Sheerness, and the results obtained are thus stated:—

1. "That the compass gave different bearings of the same object when placed in different parts of the ship.

2. "That when the ship's head was on the magnetic north or south, no effects arose from local attraction; proving that, when the ship was in that position, the attraction of the various masses of iron on board acted in unison with the magnetism of the earth.

3. "That when the ship's head was east or west, the effect of local attraction was greatest, and that, at the intermediate points, the deviation of the needle varied nearly in proportion of the sine of the angle between the bearing of the ship's head and the magnetic meridian to radius.

4. "That the maximum variation in the same compass would be different in different parts of the world; or, in other words, that the force of the local attraction of the vessel varied with the dip of the magnetic needle, or in proportion to the distance from the magnetic equator."

On these conclusions of Captain Flinders, perhaps it may be proper in this place to remark that it has since been proved, beyond all manner of doubt, that the points of no deviation in many ships are not north and south [especially in steam-vessels — see the Tables in this work], and that the points of *greatest deviation* are not always east and west; and this may readily be conceived to be the case whenever the iron of the ship, or rather its magnetic influences, may not be symmetrically disposed with respect to the compass.

In 1817, Mr. Bain published a pamphlet, proving, in the most palpable way, the necessity and importance of attending to the subject; and since then, Professor Barlow (a name so well known to us all) has given to the world his elaborate investigations, to which, with others of a yet more recent date, I have already had occasion to refer; but I may here notice some of the leading results obtained by Mr. Barlow, in his researches to discover some principle of computation or other method for correcting the source of error arising from the local influence of ships upon the compass in all parts of the world.

The results of the first experiments were published in 1820, in his "Essay on Magnetic Attractions," and, in 1824, an extended edition of that work developed, according to his view, the mathematical principles which regulate the action of unmagnetic iron upon a magnetic needle.

Mr. Barlow ascertained that a ball of iron produced no disturbance of the compass-needle, when the latter is situated in any part of a plane passing through the centre of the ball, and at right angles to the direction of the dipping-needle in the place where the experiment is made; the angle of the inclination of this plane to the horizon being the complement to the angle of the dip.

The section of this "plane of neutrality" (or, as it was first denominated, "plane of no attraction"), by a horizontal plane passing through the centre of the ball, will be a line directed to the magnetic east and west; and if a hollow sphere of considerable diameter be supposed to extend around the ball, and to be concentric with it, the plane above defined will, by its intersection with the sphere, form a great circle, which may be regarded as the *magnetic equator* of that sphere with relation to the magnetic action of the ball.

"Another plane of neutrality is constituted by a vertical plane, also passing through the common centre of the ball and sphere, and including the magnetic direction, that is the line of the dip: this plane is evidently that of the magnetic meridian; and it also intersects a great circle on the imaginary sphere."

With respect to certain modifications which have been introduced into the theory of this subject, such as "that there is no plane in which the attraction of a sphere, or, in general, of any body magnetised by the earth's influence becomes evanescent," the reader is referred to the elaborate disquisitions of M. Poisson; but, to proceed,—Mr. Barlow having settled many preliminary definitions, such as the magnetic latitude and longitude, the law of action deducible from his experimental investigations is, that "the amount of the angular deviation of a compass-needle, the motion of which is limited to a horizontal plane, from the true magnetic meridian, at any point on the surface of the sphere, is such that the tangent of the angle of deviation is directly proportional to the rectangle of the sine and co-sine of the latitude of that point, multiplied into the co-sine of its longitude."

The influence of the mass, and likewise the surface with relation to the mass of the iron sphere in modifying its action, were made the subjects of investigation, from which it appeared that the hollow shell produced a similar deviation to a solid ball of equal diameter, provided that the thickness of the shell was more than $\frac{1}{30}$ of an inch, and that its distance from the needle was such as the inductive power of the said needle would not act upon it.

Mr. Barlow, after many investigations, proposed the following ingenious contrivance to neutralise the effect of the ship's iron upon the compass, viz.: Since it was found to be possible to place a ball of iron in the same line of direction, with regard to the compass, as that in which the combined action of the iron of the ship is exerted, and to bring it to the exact distance at which its action would be equal to that of the ship's iron, it was obvious that a ball so placed would, instead of destroying the deviation of the compass, double its amount, or, strictly speaking, double the tangent of the angle of deviation.

As the effect to be obtained depended upon the surface and not on the mass of iron, Mr. Barlow found it desirable to employ circular plates or discs of iron instead of balls.

The proper position of the plate, with regard to the compass, being determined on shore by experiment, so as to make its influence upon the compass equal to that of the ship, previously ascertained, then its application at sea, in the manner before described, would double the amount of deviation; and hence, by changing the position of the plate in an opposite direction, but in the same line before described, the neutralisation of the effect of the ship's iron upon the compass was accomplished, at least within narrow limits of error, over a large portion of the globe, as may be seen by referring to the cases mentioned in the "Essay on Magnetic Attractions."

It must be remarked, however, that since the introduction of so much *wrought* iron into the structure of ships, such as the iron diagonal riders, knees, &c., and in steam-vessels large portions of the machinery, which, as has already been noticed in another part of this work, may, from the hardness occasioned by hammering, assume the character of permanent magnets, while other ferruginous portions of the ship remain soft, and, from the fact of changes of temperature affecting unequally the inductive magnetism of iron of different degrees of hardness, these circumstances may necessarily be expected to introduce some degree of uncertainty into results obtained by the application of one plate of iron of a certain degree of hardness, to correct the combined effect of masses of a different character.

In Volume IX. of the "Quarterly Journal of Science" (1820), there is a most valuable paper by the late Dr. Young, entitled "Computations for clearing the Compass of the *regular effect* of a ship's *permanent* attraction," and a Table of corrections founded thereon is inserted, in which, according to the change of dip and the apparent distance of the ship's head from the magnetic north, a logarithmic correction is obtained; but the remarks in the preceding paragraph respecting the different character of portions of iron on board ship appear to be equally applicable to such a Table, and thereby rendering actual observation preferable to computation on this point for practical purposes.

For an exact description of the plan and principles of correcting the compass in *iron* ships, by means of magnets, &c., the reader has already been referred to a paper by the Astronomer Royal in the "Philosophical Transactions," 1839; and with respect to Professor Barlow's system of correcting those in *timber*-built ships by means of an iron disc, a full detail will be found in his "Essay on Magnetic Attractions."* In this place, however, it may suffice to observe that the Committee considered it safer, for the general purposes of navigation, that the errors of the compass should be ascertained by actual observation in each ship (due care being taken to place the compass in a proper position), and allowance be made for the same in the ship's reckoning: the method of examining the deviations at sea and in port, and thereby reforming the Tables whenever the ship may change her geographical position, being fully explained in the "Practical Rules," with which all her majesty's ships are now supplied.

As in all iron-built ships it is indispensable that the standard compass should be *always* at its proper *elevated* position, it results that no *iron* vessel should be rigged as a brig, because the main boom would interfere with that arrangement.

The Polar expedition of 1818, and the subsequent voyage of Sir Edward Parry, afforded ample opportunities for scrutinising the subject of local attractions in timber-built ships; and having, through the kindness of Lieut.-Col. Sabine, R.A. (then astronomer to the expedition), had the perusal of his private journal, I find there recorded many most interesting facts, in addition to those published.

In the voyage of Sir John Ross constant observations were made on board the Alexander and Isabella, from which it appeared that, before they had reached Greenland, the compasses of one ship differed as much as eleven degrees from those of the other; so that to sail parallel, as indicated by compass signal, would be impossible.

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* Mr. Walker has recently proposed a plan for correcting the compass in iron ships, but in our present state of knowledge of its merits, it would be premature to remark thereon.

But, further than this, it was likewise observed that the same compass gave results differing ten degrees in different parts of the same ship.

In the voyage of Sir E. Parry, as he passed through Barrow Straits, the compasses became totally useless, showing that, although the magnetic force of the earth would be greatest at the magnetic pole,* yet the horizontal or directive power of the needle would cease; so that, in approaching the pole, the directive power of the compass would gradually diminish, and thus leave the iron in the ship (remaining in the same position), to exert a greater influence over its direction.

In the "Quarterly Journal of Science," 1820, there is an interesting paper by Mr. Fisher, relative to observations made on board the Dorothea and Trent, in Captain Buchan's Polar Expedition, and from which the following passage is quoted:—

"On the 1st of June, 1818, a point of land on the N.W. coast of Spitzbergen was seen and observed to bear S.E., the ship being at the time on the larboard tack, and her head in the direction of east; but, on putting her on the other tack, the same point of land bore south, the ship's head being then in the direction of N. by W., making a difference in the bearings observed on each tack of no less than four points or forty-five degrees."

Captain Beechey and Sir John Franklin were lieutenants in this expedition, and made numerous observations on the subject.

In Mr. Scoresby's "Account of the Arctic Regions," vol. ii. p. 537, there is a copy of a paper which was read at the Royal Society, Feb. 4, 1819, giving an account of certain experiments made by him on the coast of Spitzbergen, in 1815–1817, showing the effect of the ship's local attraction.

In 1820, Capt. W. Baldey reported the experiments made on board his majesty's ship Leven. See also Capt. Owen's observations on board the same ship.

In 1820-22, Captain Vidal and the late Captain Mudge, then lieutenants, reported also the experiments made on board their respective ships. In his majesty's ship Barracouta there was no less than sixteen degrees' deviation on the maxima points; and about the same period, Captain Basil Hall and Mr. H. Forster reported upon experiments made on board his majesty's ship Conway in Portsmouth

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* See remarks on the magnetic poles of *verticity* and *intensity* not being coincident.

Harbour and on the South American station, by which it appeared that, in Portsmouth Harbour (dip 70°½ N.), ship's head W.S.W., the maximum deviation was 4° 58′ W., and at Valparaiso (dip 38°¾ S.), the deviation (ship's head in a similar direction) was 0·40 E.

In 1823, Captain Douglas C. Clavering reported upon experiments made by himself, Captain Sabine, and Mr. Forster, on board the Griper at the Nore, and at Fair Haven, Spitzbergen (latitude 79° 50′ N. and longitude 11·40 E., dip 81° 11′ N.), showing that in the Griper the deviation in England, when the ship's head was to the W., was 13°½ W., and at Fair Haven, 29° W.

The local attraction of the Griper being greater than in the former voyage with Captain Parry, Captain Clavering could only account for it by the chain cables and patent capstan, and he suggested that the Griper should be swung again when these were taken out; and the result proved the fact that in England, when the spindle of the capstan was taken out, the maximum deviation was reduced to five degrees.

Captain Flinders, while in the command of the Investigator, appears to have adopted the plan of placing the surveying compass in the centre line of the ship, and a similar plan was adopted on board the Leven, in 1820: and with reference to the application of a standard compass on board her majesty's ships, the necessity for such a system cannot be better described than in the following quotation from Sabine's "Pendulum and other Experiments," pp. 428-9 (1825):—

"In ships of war especially, the reckoning is further embarrassed by a difficulty, less obvious, but not less generally operative, by which, if not properly provided against, the knowledge of the true course which the ship has made is necessarily rendered very uncertain: it arises from the usual practice of directing the course by the binnacle compasses, which are two in number for the convenience of the helmsman; and being placed one on the larboard and the other on the starboard side of the midship line, with a space between of greater or less extent, according to the size of the vessel, can scarcely fail, and are, in fact, generally influenced differently by the ship's iron; and being subject to different *systems* of attraction, the compasses not only disagree, but their disagreements vary according to the direction of the ship's head, the amount of the dip of the needle, and the force of terrestrial magnetism. It is customary always to steer by the weather compass, and thus each is liable to become in its turn the directing compass for periods of more or less duration, and the corrections of the courses for the disturbing influence of the ship's iron become so various and complicated, as to render the deduction of a correct reckoning practically unattainable. For example, the binnacle compasses of the Iphigenia, on her passage from England to Madeira, were observed to differ from each other half a point in one direction when on south-westerly courses, and less than half a point in the opposite direction when on easterly courses, the indications of the compasses having crossed each other, and agreed at some intermediate point; it was requisite, therefore, that the correction to be allowed on every course by each of the two compasses should be ascertained, and that the compass by which each course was directed should be specially recorded, in order that the true course should be known.

" The most obvious mode of preventing so much inconvenience and trouble, as well as the more correct practice, is to direct and note the ship's course by one compass only, stationed permanently in some convenient situation without reference to the helmsman, and to use the binnacle compasses solely to steer by, on the point which may be noticed at the time to agree with the magnetic course shown by the standard compass. By employing an azimuth compass for the latter purpose, the advantage is gained of enabling the variation to be observed directly with the compass by which the course is governed, and thus of avoiding intermediate comparisons, in which time is occupied and errors frequently introduced. This arrangement of a standard compass was adopted by Captain Clavering in the Pheasant, and subsequently in the Griper, and was found to answer its purpose perfectly, and to be attended with no practical inconvenience whatsoever."

Professor Barlow's "Essay on Magnetic Attractions," 1824, is full of well-authenticated facts deserving the most serious attention. His plan of correcting the compass by means of an iron disc is therein explained. It has, however, been already noticed, that the plan preferred by the Committee is to ascertain the deviation of the compass upon each point, and allow for it accordingly.

Numerous instances of the serious consequences which accrue when the deviations of the compass are unknown or unattended to, have been published from time to time in that valuable work the " Nautical Magazine," and from which the graphic descriptions by Mr. William Walker, Queen's Harbour-master at Plymouth, of some occurrences which came under his own notice, are here quoted.

Mr. W. observes, that "on the 30th of December, 1818, being in command of a king's store-ship laden with *iron tanks* and bound to Plymouth, and knowing that these tanks would excite an influence upon the compasses, a course was steered W.N.W. from St. Catherine's Point for the Start. There was a fresh breeze at east, and clear weather, but at daylight the Start bore N.N.E. twenty-one miles! In this case, the ship was at least eight leagues farther to the southward than she ought to have been by steering W.N.W. I was not then aware of the fact that an *iron tank* would exert a magnetic influence equal to a solid cube of the same dimensions.

"On the 26th of March, 1803, his majesty's ship Apollo sailed from Cove of Cork, with a convoy of seventy sail of merchant-ships; on the 2d of April, at three in the morning, *the frigate and forty sail of her convoy* went on shore on the coast of Portugal, at a time they imagined themselves three degrees to the westward. The loss of these ships may be ascribed to the local attraction of the *frigate* upon her compasses, for about thirty sail of the convoy had during the night wore to the north-west, and escaped destruction: this convoy had been steering for several days in a south-west direction. The north point of the frigate's compass would be drawn forward, thereby indicating a course farther to the westward than the ships were really steering, and hence the melancholy loss of so many ships!

"Being in charge of her majesty's ship, Royal William, recently launched and equipped at Pembroke, I was directed not to put to sea without two steam-frigates, ordered to accompany me to Plymouth: they arrived and towed the ship down Milford Haven, and out to sea. Sail was then made with a fresh breeze from north-west: there were, however, symptoms of the wind drawing to the westward, and I shaped a course for Scilly, instead of for the Land's End. Captain Oliver, of the Dee, hailed, 'How long do you intend steering on this course?' I replied, 'Till I make Scilly light.' The wind freshened, the ship increased her pace to eleven or twelve knots, and the steam-frigates were left far behind. We made Scilly light, and bore up for the Longships, passing between them and the Seven Stones,—passed up Channel, and ran into Hamoaze, the wind having drawn to the southward. The steamers had continued their course with sail and steam, and made breakers under their bows on the north side of Scilly, the light being eclipsed by St. Martin's Head. They backed their engines, shortened sail, and stood to the north-west till daylight, when no three-decker was to be found! They searched the rocks in vain, and proceeded to Plymouth, alarmed for the safety of the Royal William. It now turned out that *their compasses* indicated a course that ought to have carried the steamers far to the westward of the Scilly Islands: the north point of the compass was drawn forward by the influence of their machinery.

"I had occasion to return to Pembroke to bring round another line-of-battle ship, taking a passage in the steam-frigate Salamander, commanded by Capt. Austin. The adventure of the Royal William induced us to make many observations upon the local attraction of the steamer during the passage. A dockyard sailing-vessel was taken in tow, and after rounding the Land's End we shaped a course for St. Ann's Point, with a firm conviction on my part of making St. Govan's Head. The wind shifted to south-west, with thick weather; and as we neared the Welsh coast, we were amused as well as *instructed*, by the master of the vessel astern standing up and waving his hat to steer more to port. He actually *cast off the tow-rope* and hauled up two or three points! We went on as before, and, as was expected, made St. Govan's Head, south-east from St. Ann's Point.

"The master of the lighter knew by *his compass* that we were steering too far to the eastward. *Our object* was to prove how little dependence may be placed in the compass of a steam-vessel, when the local attraction is not known.

"The steamer San Juan ran on shore on the coast of Portugal; and, more recently, the Thames, instead of making the Longships, made Scilly, and was lost, &c. &c.

"Instances might be multiplied to show that in north magnetic latitude ships will almost always be to the *southward* and *eastward* of their reckoning, by reason of the north point of the compass being drawn forward, and the south point drawn aft by local magnetism; but in the southern magnetic hemisphere things will be inverted, and ships will generally be found to the *northward* and *westward* of their dead-reckoning!"

The foregoing remarks bear upon the principle that the attractive iron of the ship was principally before the compass and below its level. I have met, however, with some cases where the iron abaft, being so much nearer to the compass, has counteracted that of the greater mass of iron forward; showing that nothing but actual experiment in each ship, however troublesome the process may be, should be depended upon.

1851. The following particulars relating to the Diligence transport, and which have occurred this year, are entirely corroborative of the preceding remarks.

Captain the Hon. R. S. Dundas, superintendent of Deptford yard, having referred to me a letter from the master in command of the Diligence, in which he represented the great errors of the compasses in the binnacle, causing the ship to be out of the reckoning between forty and fifty miles in the course of two days; and also stating that when the ship was steered by the azimuth compass, on a different part of the deck, that no such error occurred. I proceeded on board that vessel at Deptford, and there observed the very wide difference in the direction of the ship's head, as indicated by the binnacle compasses, and by the azimuth compass placed on a different part of the deck.

My first impression was, that as the ship had several iron stores on board, the errors might have been caused by their influence; but these stores were stowed before and below the level of the compasses, and, consequently, if any effect were produced by them, it would be to cause the ship to be to the southward of the reckoning by reason of their position; whereas, on referring to the log-book, it appeared that the ship was to the northward, indicating, that if the influence proceeded from iron it must have been abaft the compass. The binnacles having been duly examined and no iron discovered about them, I commenced a search below in the direction in which iron would produce a similar error to that reported, and presently discovered, under cover of some wainscot painting, a square iron casing, extending from the cabin stove to the deck, the top of which iron was only two feet from the compass needle in the binnacle.

This iron casing, concealed as it was beneath the coating of paint (and which had been previously supposed to be copper), was at once removed; and on the Diligence being swung by Mr. Petley at Greenhithe, the result of the arrangements made proved highly satisfactory—all the compasses working well, and the deviations proving extremely small.

The following extract from Captain Lynn's "Introduction" to his "Tables" bears so strongly upon the subject of local attraction, and especially as respects the dispersement of convoys (already alluded to at p. 4), that it deserves most especial notice:—

"In confirmation of the certainty of the existence of such an effect, and of the necessity of guarding against it, the following circumstance, to which the author, Captain Lynn, was an eye-witness, will show.

"In February 1809, a valuable fleet of outward-bound East Indiamen sailed from Portsmouth, under convoy of his majesty's ship Clorinde, Captain Briggs, and having rounded St. Catherine's Point, shaped their course to the westward, with a fresh northerly gale and every appearance of bad weather. It was soon observed that the Clorinde was steering considerably to the southward of the proper Channel course, and which, in the early part of the night, might reasonably have been attributed by other ships to the expectation the commodore might have of a change of wind to the southward: the wind, however, remained to the northward, and the fleet continued to steer by the compasses of the Cuffnells W. ½ S. instead of W. by N. ½ N. or even W.N.W. under the then existing circumstances. We were perfectly aware that such a course must bring us in with the Casketts; and kept accordingly to the northward of the Clorinde, and also a good look-out for the lights. At midnight they were discovered under the lee, at no great distance from the ship; and immediately after the firing of guns in all quarters sufficiently indicated the distress of the fleet. The 'Cuffnells' was immediately wore, and all possible sail carried to keep out of the influence of the Race of Alderney. The whole fleet was consequently dispersed, several dismasted, but fortunately none were lost. Upon meeting again at Portsmouth, Captain Briggs and the officers of the Clorinde declared that the accident was entirely owing to their having been deceived by their compasses; by which they had steered during the night from W. by N. to W. by N. ½ N., whilst, by the compasses in other ships, they had been steering W. and W. ½ S. This deception could have been no other than the effect of local attraction on the Clorinde's compasses.

The following note from a most experienced officer, now Assistant Master Attendant at Sheerness Dockyard, shows so clearly the necessity for caution in seeing that no iron is improperly placed near the compasses, that we insert it at full length, as a useful auxiliary to the observations made upon that subject in the preceding portion of this work:—

"H.M. Dockyard, Sheerness, February 8th, 1851.

"Sir,—In addition to the many interesting details published in your valuable work respecting the dangerous effects of iron being placed too near binnacle-compasses, I beg to state one to you which I believe has escaped your notice.

"In the latter part of 1834, H.M.S. Rattlesnake, commanded by the late Capt. W. Hobson, was fitted out at Portsmouth for the East Indies. I was master of her. We touched at Plymouth, where I had good observations, and proved the correctness of the chronometers, and left the latter port for Madeira with a fresh easterly wind, that continued nearly the whole passage. After leaving the land, we had not a good observation for perhaps three or four days; and when sights were got for the chronometers, they placed the ship between two and three degrees to the westward (I believe) of her supposed position by the dead reckoning. This difference, although great, was attributed either to a strong current or the effects of bad steerage; but when, on the succeeding day, the chronometers again showed her to be very considerably to the westward, our attention was called to the compasses, the cards were changed, and every bit of iron that we could discover removed from the vicinity of the binnacles: notwithstanding which, the same results of the ship being found very much to the westward of her position by dead reckoning, occurred every day until our arrival at Madeira: here the ship's place of anchorage, taken by cross-bearings with compasses placed near the taffrail, or at the gangway, corresponded as nearly as possible with that shown by the chart; and finding by observations (equal altitudes) taken on shore, that the chronometers were quite correct, we all felt convinced that the ship had been subjected to a very strong and unusual current.

" During the passage from Madeira to Teneriffe we continued daily to find the ship, by chronometric observations, considerably to the westward; and, on anchoring, found by bearings taken from the compasses *in* the *binnacle,* that they placed her very nearly, if not quite, on shore! We were now more perplexed than ever; all the compasses were tried and compared at various parts of the ship, and a great difference was found in either of them that happened to be placed near the binnacles: our search for iron was redoubled; but for a long time in vain. At length, between the after part of a beam and the bulk-head of the fore-cabin a casing was taken down, and we found that the spare *iron tiller* (which had previously been triced up over the heel of the bowsprit) had been shifted aft, and boarded in there. This was directly under the binnacles, and had, of course, been the cause of the greater part, if not all, the difference between the ship's place by dead reckoning and that ascertained by observations.

" We were most fortunate in having had good chronometers, fine weather, and plenty of sea room; otherwise such an error or over-sight might have been attended with the most fatal consequences; but, sir, since, through your exertions, so much attention is paid to ascertain the deviation and errors of all compasses, and so much more care taken of that indispensable and most valuable instrument, a recurrence of such a case as I have here stated cannot now take place.

"I have the honour to be, Sir,
"Your obedient, humble servant,
"CHARLES POPE.

"*Capt. E. J. Johnson, R.N., Admiralty.*"

Note on the Compasses constructed upon the Plan recommended by the Committee.

A good deal of discussion having taken place before it was resolved to adopt the plan of four edge-bar needles parallel to each other, and as I then stated my apprehension that a considerable loss of magnetic power would eventually ensue by such an arrangement, it may be satisfactory to the majority, who took a different view, to mention that I have tested a great many of the standard compasses with needles so arranged, after they had been in use on foreign stations upwards of three years; and I have at this moment a table of results before me, showing that the compass needles alluded to, which had been employed in her majesty's ships in the East and West Indies, North and South America, on the coast of America, on the coast of Africa, and in the North Sea and English Channel, have, with only two exceptions, preserved their magnetic power in a remarkable degree. In most cases the loss did not exceed $\frac{1}{20}$th of their original power, although oxidation had taken place in many instances, and in some no loss of magnetism had been sustained.

In the two exceptions above noticed, the needles had lost, in four years, one-seventh of their original power, so that, as the question now stands, it would appear that it is more to the constant friction of the pivots and caps than to the loss of magnetism of the needles, that imperfect working is to be looked for.

It may also be satisfactory to the members of the Committee, and to Mr. A. Smith, who interested himself in the theoretical investigation of the plan of placing four needles upon a compass-card, to know that, on a repetition of the experiments, as to what effect would be produced on a compass so constructed, in case any one or more of their needles should lose magnetic power, their former conclusions have been fully verified, inasmuch as in the extreme case of taking away one of the outer needles altogether from the card, the correct direction of the compass in the magnetic meridian was still maintained, provided the other needles remained parallel to each other and the card was properly balanced.

In the course of my experience, I have not yet met with any change in the direction of compasses constructed in the manner before described, except when the parallelism of the needles had been evidently disturbed by force, accidentally or otherwise, or where the centering of the card, pivots, or framework of the prism had been distorted by a similar cause.

1850. Several instances having occurred wherein the prisms were found to be out of adjustment, when the compasses were returned into store; they are now adjusted to medium sight and fixed, the screw for focal adjustment being discontinued.

The practical disadvantage of employing four needles appears to be in those cases where transparent cards are required, and the compass is lighted from below, under which circumstances the needles and their framework are found to eclipse too much light.

1851. With reference to the remarks, at page 56, on the difference of deviation produced by what are termed telescopic funnels of steam-vessels, I have, since the said remarks were printed, made a few experiments with hollow iron cylinders placed inside of each other, leaving a space of about one-eighth of an inch between each, the object in view being to ascertain whether the whole amount of the difference of deviation were due to the elevation and depression of the funnels with respect to the compass, or whether a portion of the said difference might be attributable to the induced magnetism of each cylinder acting upon each other. The following are the results which I obtained, and which appear to confirm the latter hypothesis.

Having placed a standard compass on one of the pedestals in the observatory and ascertained the magnetic meridian for the moment, the largest or external iron cylinder, No. 1, was brought in and placed to the eastward of the compass and below its level. This produced a deflection of the north end of the needle 10° 10′ to the east.

No. 2 Cylinder was then placed inside of No. 1, when the deflection was increased to	12° 15′ E.
No. 3 Cylinder was then placed inside of No. 2, when the deflection was again increased to	14 15 E.

The compass having been removed, Hansteen's magnetic intensity instrument was placed with the centre of its needle (as nearly as I could adjust it) in a similar position to that which the centre of the compass had occupied, when the following results were obtained:

	Time of 100 Vibrations starting from an Arc of 18°.
Previous to the Cylinders being brought into the Observatory...	6′ 57″
No. 1 Cylinder, in place	6 51
No. 2 Cylinder, inside of No. 1	6 47
No. 3 Cylinder, inside of No. 2	6 45

The intensity instrument being removed, a dipping-needle was then employed, and the cylinders being placed to the *south* of the instrument the following are the results of the observations:—

	Mean Readings. Dip.
Previous to the Cylinders being brought into the Observatory...	68° 37′
No. 1 Cylinder, in place to the *south* of the instrument	70 10
No. 2 Cylinder, inside of No. 1	70 27
No. 3 Cylinder, inside of No. 2	70 37

Notes on several Descriptions of Compasses designed by different individuals.

Having referred, at page 74, to the erroneous conclusions which are sometimes drawn as to the comparative merits of different compasses, inasmuch as the steadiest is not unfrequently considered the best, although some defect as relates to accuracy might produce that effect from the causes already explained; yet as compasses suspended in the ordinary way have proved too unsteady for use in small vessels propelled by the screw, and in boats, &c., various ingenious appliances for steadying the card have been tried from time to time in such vessels, and also when guns are fired. (See pages 77 to 82.)

Besides the compasses of peculiar construction which have been mentioned in the preceding part of this work, we may add that of Commander West, R.N., and also a compass on the plan of Commander Bootakoff of the Russian Imperial Navy, described in the "Nautical Magazine."

With respect to boat compasses, the reports of the working of Mr. Preston's, Mr. Dent's, and Mr. Walker's compasses are the most favourable.

The boat's liquid compasses of Mr. Preston (made by Mr. Jenkins), are now proposed to be further improved by an invention of Mr. Ramage, who professes to remedy the inconvenience of air-bubbles forming on the surface by means of a self-acting contrivance. One of these compasses, made by Mr. Hughes, is at present under trial.

With reference to the experiments on compasses in small and fast steamers, and those propelled by the screw, mentioned at page 79, it is only justice to Messrs. Gray and Keen to state, that since the period when these experiments were made they have supplied an improved compass to H.M. yacht Fairy, which has been reported very favourably of by Mr. Welch her commander, and in consequence of which another compass of the same description has been ordered for further trials. Commander Crispin, of H.M. yacht Victoria and Albert, speaks also most favourably of this compass on board the Fairy.

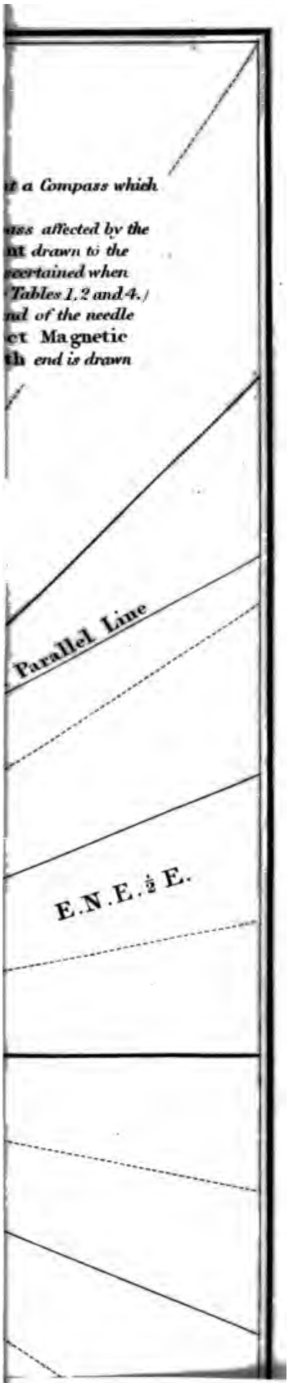
In considering other circumstances than the mere steadiness of the compass, it may here be mentioned that human ingenuity has been at work to connect the compass with the clock in such a manner as to register on a card the errors in the ship's course which may have been produced by bad steerage in a given space of time. The best contrivance of this kind, which I have seen, is that of Mr. Napier, C.E., of London.

In ships of war, where three persons are constantly on the look-out for careful steerage, viz. the helmsman, the quartermaster, and the officer of the watch, such an appliance may not be needful; but in ships where the helmsman alone is chiefly concerned the case is different.

I cannot conclude these remarks without observing, that the efforts which have been made of late years to improve the mariner's compass have not been confined to the instrument in its primitive form, but endeavours have also been made from time to time, and are now making, with the view of constructing a compass which shall discover the amount of deviation caused by the ship's iron, without reference to astronomical observations, or to the usual process of simultaneous observations when swinging the ship. None of these contrivances, however, which have as yet come under my notice, appear to satisfy all the conditions required for such an important purpose.

Be it observed that these inquiries are not limited to England, but are proceeding both in France and America. The propositions of M. Bisson of Paris, which failed to be realised in the experiments tried under my immediate superintendence in 1849, were directed to this purpose, and he is still pursuing his investigations; and Mr. St. John's compass, shown in the Exhibition, appears to have the same object in view. I understand, also, that others in this country are in the course of construction, but of which it would be premature to remark at present. In connexion with this subject I may mention, however, that as far back as 1824, when not far advanced in the knowledge of the subject, I tried upwards of fifty different arrangements of magnetic needles to accomplish this purpose, but without success; and since that period I have greatly added to the number of unsuccessful experiments. The experiments alluded to, however, I registered in a book as they took place, together with the numerical results produced by the application of iron and magnets in different positions with respect to the various arrangements of magnetic needles; and although I have been compelled to name the said old register *A Book of Errors*, yet it has proved extremely useful to me in showing aspirants in the same line the tracks which have already been beaten: nevertheless I hope that those who are at present experimenting on a subject of so much importance may be more successful than myself.

Various plans have been, at different periods, proposed for isolating a ship's compass from the effects of local attraction; but it is, perhaps, almost superfluous to state to persons conversant with magnetism, that, so far as our present knowledge extends, no such desirable object has been effected.


a Compass which
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Tables 1, 2 and 4.)
nd of the needle
ct Magnetic
th end is drawn
Parallel Line
E.N.E. ½ E.

EXPLANATION OF THE WORKING DIAGRAM.

THE lines drawn upon the CHART are intended to represent a compass which is not affected by local attraction, consequently its north point indicates the *correct magnetic north.*

The moveable Card represents a ship's compass, or that which is affected by the iron in the ship, and the deviation so produced is called east or west according as the *north* point of the ship's compass is drawn towards the east or west of the CORRECT MAGNETIC NORTH.

By turning the *north* point of the moveable Card to the east or west of the *correct magnetic north,* according to the deviation ascertained with the vessel's head in a given direction, the *correct magnetic course* which she would be actually steering will be shown by that point or line *upon the* CHART which corresponds with the ship's APPARENT course there shown by the moveable Card.

It will likewise be seen in what manner the bearings of objects in every direction are affected while the vessel's head remains in the same direction.

When a *correct magnetic course* is to be shaped by the Standard Compass, it is only necessary to refer to the Table for the amount and direction of the Deviation on the particular point required, then turn the moveable Card accordingly, and observe what point of it corresponds with the *correct magnetic course* or line upon the CHART.

EXAMPLES.

1. If the ship's head by the Standard Compass be E.N.E. and the deviation upon that point be 5° 22′ E., then the real magnetic direction of her head will be 5° 22′ to the right hand of E.N.E., or about E.N.E. ½ E.

2. If the ship's head be on the same point, as in the above example, the bearings of two islands be S.E. and W. by S. by the Standard Compass, then by applying the same correction 5° 22′ E.,

and in the same way, the real magnetic bearings of those two islands will be S.E. ½ S. and W. ½ S.

3. Supposing it were required to make a CORRECT MAGNETIC S.W. course by the Standard Compass, the deviation being 3° 8′ W., or about the third of a point, with the ship's head in that direction; this must obviously be applied *conversely*, and the ship must be steered S.W. ⅓ W., because this course, when corrected by applying 3° 8′ to the left hand, will give the real or *correct magnetic course.*

This will be clearly understood by turning the north point of the moveable Card one-third of a point to the west of the *correct magnetic* north; and then, by referring to the *correct* S.W. line on the CHART, it will be seen that the point of the moveable Card which that line bisects is S.W. ⅓ W., the course to be steered by the standard compass to make good a *correct magnetic* S.W. course.

4. Suppose that the fifteen steam-vessels named in Table I. were driven by stress of weather to seek shelter in such a harbour as is here represented, and that in the Sailing Directions the only mark given to lead between the shoals was, *"to bring the church to bear W.S.W. by compass, and steer in with it upon that bearing:"*

By turning the north point of the moveable compass-card to the left hand till it corresponds with the amount of deviation ascertained on board the respective vessels, when their heads were towards the W.S.W., the proper course for each vessel to steer in between the dangers (corresponding to the correct magnetic W.S.W.) will be seen: but suppose that these vessels were steered for the harbour by the above bearing, without their commanders having ascertained the deviation or making any allowance for it, then it is clear that eleven of the fifteen would be run upon the sunken rocks near the entrance; because, in order to bring the church to bear W.S.W., when the vessels' heads were in that direction by their respective compasses, they must have been too far to the northward, as is evinced by the parallel line PPL drawn upon the chart (from the church), so as to correspond with the W.S.W. line of a ship's compass having half a point westerly deviation.

By examining Table IV., which contains the deviations ascertained on board several of H.M. iron steam-vessels, it is obvious that they would be yet more wide of their mark, and that some of them under such circumstances would even be run upon the shoal to the south of the entrance, by reason of their deviations being in an opposite direction.

5. Referring to the Charts and Sailing Directions of the more intricate channels of our own coast, it appears that the bearings and compass-courses are often the only guides.

The pilot of H.M. steam-sloop Vesuvius (see his Report, page 15), in proceeding in the Fairway from the Sunk towards the Shipwash, had to steer N.E. by N. instead of N.E., which is the course given in the Sailing Directions. By Table I. it will be seen that when the Vesuvius' head was towards the N.E. there were ten degrees (or nearly a point) *easterly* deviation, so that the pilot very properly made that allowance.

By drawing the *north* point of the moveable Card ten degrees to the eastward of the correct magnetic north, it will be evident that if the Vesuvius had been steered N.E., according to her compass, she would in reality have been sailing in a N.E. by E. direction, and would thereby have been run into danger; but, in order to make a correct magnetic N.E. course, she was steered N.E. by N.

For other particulars see explanation of the diagrams at pages 25–31.

The following form of a Deviation Table, for use while the ship does not change her magnetic latitude materially, will be found advantageous.

1. Direction of Ship's Head or Course by the Standard Compass.	2. Deviation of the Standard Compass.	3. *Correct Magnetic Course* which the Ship is actually sailing.	4. Course to be steered by the Standard Compass to make good a *Correct Magnetic Course*, as per first Column.
	Example I.		
S.W.	3° 8′ W.	S.W. ⅓ S. nearly.	S.W. ⅓ W. nearly.
	Example II.	("Vesuvius.")	
N.E.	10° 0′ E.	N.E. by E. nearly.	N.E. by N. nearly.

Graphic Method of representing the Deviations.

Mr. Archibald Smith, whose valuable investigations in magnetism and method of computing a table of deviations from observations, have already been mentioned in the preceding part of this work, has forwarded to me the following graphic method of delineating the deviations of a ship's compass, as designed by Mr. James R. Napier, of the celebrated firm of Messrs. Robert Napier and Sons, of Glasgow, engineers and iron ship-builders; and Mr. Napier has since kindly sent me a copy of his plan upon a large scale, which, however, it has been found necessary to reduce for insertion here.

Although it is by no means intended here to lessen the importance of observing at all times upon as many points as practicable—a system which has been inculcated throughout this work—yet this ingenious plan of Mr. Napier will prove a useful auxiliary when the deviations cannot be observed upon all or the greater number of points, provided that the primary curve has been carefully determined, that the position of the iron in the ship be not changed, and provided also that the succeeding observations, when the ship has changed her geographical position, be made by experienced observers and with accurate instruments. This method may also be advantageously made use of when observations have been made on a large number of points.

The preliminary operations in Mr. Napier's method (and from which the primary curve is derived) are those of swinging the ship, &c., described in the Practical Rules.

When circumstances prevent observations being made with the ship's head on many points, those most important to observe upon are the N.E., S.E., S.W., and N.W., the next in importance being N., E., S., and W.; or, according to this graphic method of Mr. Napier, the ship's head being near to those points will answer the purpose. This mode of representing the deviations has the advantage of not requiring computations.

Description of the Diagram.

The diagram consists of a vertical line of convenient length, divided into 32 equal parts, the divisions representing the 32 points of the compass in the following order, beginning at the top, North, N. by E., N.N.E., &c. The line is also divided into 360 equal parts, representing degrees, and these divisions are numbered from 0° at the top to 360° at the bottom. They are also numbered, according to the usual mode of dividing the circumference of the compass-card, from 0° at North and South up to 90° at East and West. The line may, in fact, be considered as the margin of a compass-card cut at the north point and straightened.

Through each of the 32 points on the vertical line a pair of lines is to be drawn, inclined at angles of 60° to the said vertical line: one, a dotted line; and the other, a plain line, as per diagram.

Construction of the Curve of Deviations.

On the vertical line take any one of the compass courses uncorrected for deviation, and take also the corresponding correct magnetic course (ascertained by applying the amount of deviation). Through the compass course draw (with pencil) a line parallel to the dotted lines, and through the correct magnetic course draw (with pencil) a line parallel to the plain lines. These two pencil lines will, of course, intersect. Mark the point of intersection with a cross in ink.*

Perform the same operation with each of the observed compass courses and the corresponding correct magnetic course. Then with a pencil and a light hand draw a flowing curve, passing as nearly as possible through all the crosses, and when satisfied with the curve in pencil, draw it in ink. This curve is the *curve of deviations.* It must always be remembered that the form of this curve depends entirely on the observations made in swinging the ship; that it is different for different ships, and for different positions in the same ship, and even for the same position it changes with a change of geographical position, or of the distribution of the iron in the ship.

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* In practice, instead of actually drawing the pencil lines, it will be generally found better to make the ink crosses at once with a pair of pen compasses in the following way. Take for centre the point in the vertical line which represents the compass course, and for radius the distance or number of degrees between this point and the point which represents the corresponding correct magnetic course, and describe a small arc of a circle near the point where it is seen that the pencil lines, if drawn, would intersect. Next take the point representing the correct magnetic course for centre, and with the same radius describe a small arc intersecting the former arc. The small intersecting arcs may be taken as the ink cross.

Use of the Curve of Deviations.

The curve of deviations may be used to find the *correct magnetic course* corresponding to a given compass course, and likewise to find the corresponding compass course to a given *correct magnetic course,* and that with the same facility, whatever the given course may be. The method is described in the two following Rules, which must be carefully attended to.

RULE I.

Having given a Compass Course, to find the corresponding Correct Magnetic Course, the Deviation being known.

Take on the vertical line the given compass course. Through it draw (or suppose drawn) a line parallel to the dotted lines and intersecting the curve. From the point of intersection with the curve draw (or suppose drawn) a line parallel to the plain lines intersecting the vertical line. The last-mentioned point of intersection on the vertical line is the *correct magnetic course* required.

RULE II.

Having given a correct Magnetic Course, to find the corresponding Compass Course, the Deviation being known.

Take on the vertical line the given correct magnetic course. Through it draw (or suppose to be drawn) a line parallel to the plain lines, so as to intersect the curve. From the point of intersection with the curve draw (or suppose drawn) a line parallel to the dotted lines, so as to intersect the vertical line. The last-mentioned point of intersection is the compass course required.

Example of the Construction of the Curve of Deviations.

Suppose that when the ship's course, uncorrected for deviation, is East, the course corrected for deviation or correct magnetic course, is E. 9° S., the curve of deviations may then be constructed by either of the following methods.

First method :—

Through the point East on the vertical line, draw a pencil line parallel to the *dotted* lines, which in this particular example will coincide with the engraved dotted line, and through the graduation

E. 9° S. draw a pencil line parallel to the *plain* lines. These two pencil lines will intersect on the right-hand side of the vertical line. Through the point of intersection draw an ink cross.

Second method :—

Instead of actually drawing the pencil lines, observe that if drawn they would intersect on the right-hand side of the vertical line, then take a pair of dividers or pen compasses. Place the pointed foot at east, and the pen foot at E. 9° S., and keeping the pointed foot fixed describe a small arc on the right-hand side of the vertical line near the point where it is seen that the pencil lines if drawn would intersect. Then place the pointed foot at E. 9° S., and draw a small arc intersecting the former arc. The intersection of these two arcs gives the position of the ink cross required.

Repeat this operation for every course upon which the deviation has been ascertained. Draw a flowing curve, passing as nearly as possible through all the ink crosses. This is the curve of deviations.

Example of the Use of the Curve of Deviations.

1. Suppose the course by compass, *uncorrected* for deviation, to be East. Note where the engraved *dotted* line, which passes through East, intersects the curve (it would be necessary to draw a pencil line parallel to the dotted lines, were it not that in this example there is already a dotted engraved line). From the point of intersection with the curve, draw a pencil line parallel to the *plain* lines. This pencil line will intersect the vertical line at E. 9° S., which is, consequently, the corresponding *correct magnetic course,* which the ship would be steering when her head was at East by the compass *uncorrected* for deviation.

2. Suppose the *correct magnetic course* to be E. 9° S.

Through the graduation E. 9° S., on the vertical line, draw a pencil line parallel to the plain lines intersecting the curve. From the intersection draw a pencil line parallel to the dotted lines (unless as in the present case there happen to be already a dotted engraved line where the pencil line will be drawn). This line, it will be seen, intersects the vertical line at E., which is consequently the corresponding course by compass *uncorrected* for deviation.

The use of the curve in all cases will be easily remembered if the following simple proposition be well understood and kept in mind :—

If from any point in the curve we draw two pencil lines, the first parallel to the dotted lines, the second parallel to the plain lines, the place where the first pencil line intersects the vertical line will represent a compass course *uncorrected;* the place where the second pencil line intersects the vertical line will represent the corresponding *correct magnetic course.*

Although this diagram is upon a small scale, it will serve to show the principle on which a larger drawing, similar to that in Mr. Napier's book, may be constructed, either upon drawing-paper, vellum, or slate, for use on board ship.

The curve drawn represents the deviations of H.M. Steam-frigate Retribution, swung at Sheerness in Dec. 1845, when her first engines and armament were on board.

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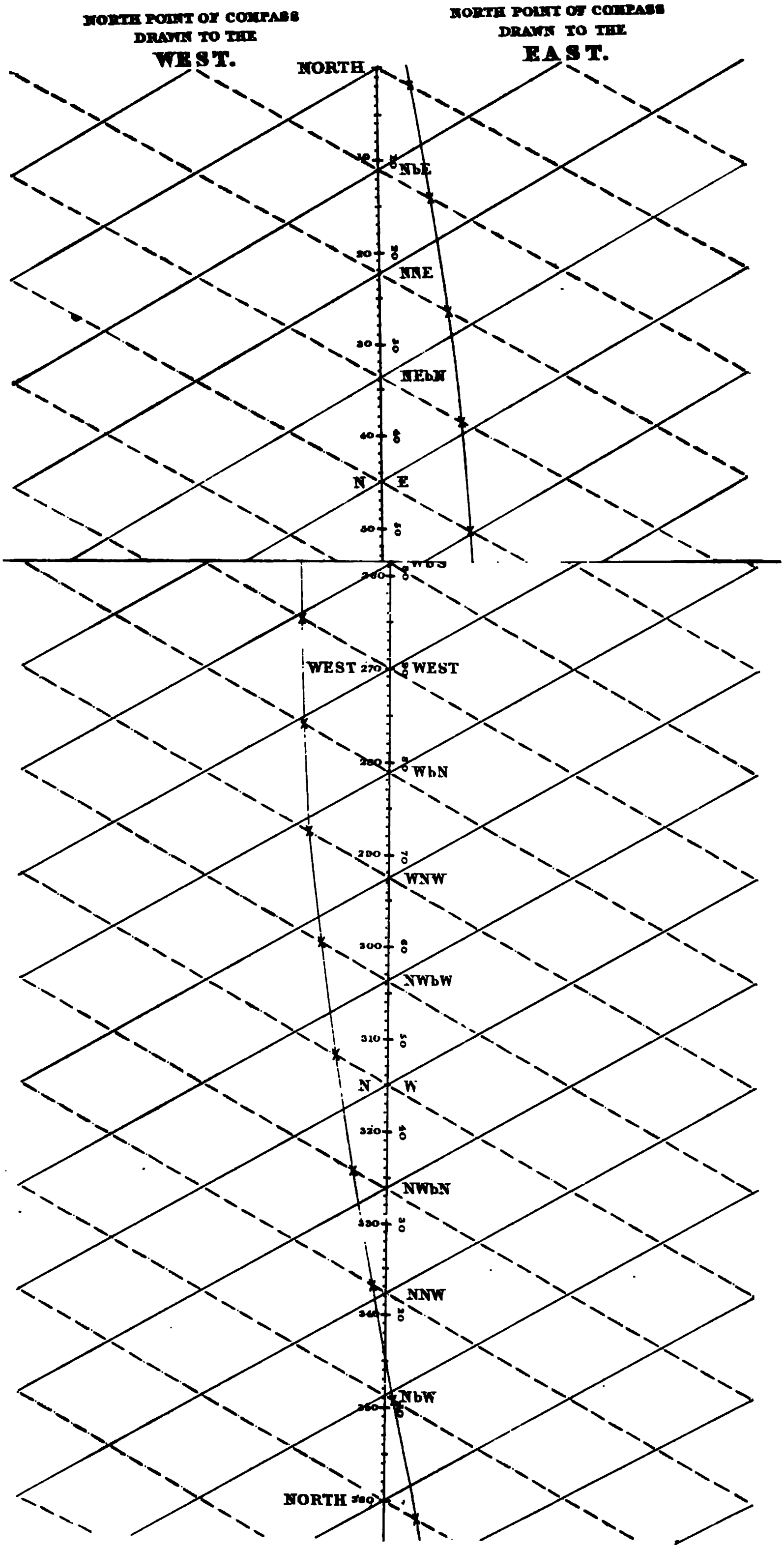
DIAGRAM,

for description see preceeding page.



12

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